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COMPLEX INNOVATION AND THE PATENT OFFICE

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ABSTRACT

As the universe of available information becomes larger and innovation becomes more complex, the task of examining patent applications becomes increasingly difficult. This Article argues that the United States Patent Office has insufficiently responded to changes in the information universe and to innovation norms. This leaves the Patent Office less able to adequately assess patent applications, and more likely to grant bad patents.

After first demonstrating how innovation has been responsive to contemporary innovation norms for hundreds of years, this Article uses information and data science methods to empirically demonstrate how innovation has drastically changed in recent decades. After empirically demonstrating the changed innovation system and the inadequate response to these changes by the USPTO, this Article concludes with policy prescriptions aimed to help the Patent Office implement examination procedures adequate to assess 21st century innovation. These prescriptions include more granular crediting for the time spent by examiners assessing applications, an increased focus on teamwork at the Patent Office, improvements to the inter partes review process, and alterations to the analogous art doctrine.

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I. INTRODUCTION

This article demonstrates how innovation has grown increasingly complex in recent decades and explores how this increase in complexity has implications for the way we set innovation incentives and assess patent applications. I demonstrate that for centuries innovation policy and the realities of how innovation occurs have co-evolved. As innovation realities change, policymakers adapt policies as they attempt to set efficient incentives. Likewise, as policies and incentives change, inventors alter the way they focus their energies transforming the way innovation occurs.

In recent decades, a series of transformational inventions have altered the way inventors identify problems, work together, and generate new ideas.[1] These changes have had wide-reaching implications for the way innovation occurs, increasing complexity as measured on a variety of dimensions. As this has occurred, policymakers have struggled to keep up with the ever-increasing pace at which the innovation process has changed, leaving innovation policy at times out-of-step with innovation reality.

In the first section of this article I briefly outline the history of patent law, focusing on how, throughout history, innovation policy has evolved in response to changing innovation practices and vice versa. This is exemplified in the development of very early Crown-granted monopoly systems that sought not just to provide incentive for the development of new technologies, but also to encourage the importation and application of existing ideas, to more recent developments like the introduction of the *inter partes* review process provided for in the America Invents Act.

The subsequent section will empirically demonstrate changes that have occurred in the way innovation work has been done over the last four decades. Here I draw on computer science and information science techniques to demonstrate that inventions have been growing more-and-more complex in recent decades. In comparison to their predecessors, inventions patented in recent years tend to draw on and integrate ideas that are more distant and disparate. This tendency towards interdisciplinarity and increased complexity exemplifies 21st century invention as inventors reach further-and-further afield for new ideas.

Building on these empirical observations, in the following section I argue that the Patent Office continues to use a 20th century patent application assessment model, and that this model is increasingly out of touch with the realities of 21st century innovation. We see this in the increasing specialization of patent examiners, as they focus on narrower-and-narrower

1. In previous work, I refer to a component of this phenomenon as "second order obviousness" as some inventions not only generate new prior art, but themselves affect the way future inventions are generated, effectively lowering the cost of new ideas and making some types of invention more obvious. *See generally* Ryan Whalen, *Second-Order Obviousness: How Information and Communication Technologies Make Inventions More Obvious and Why the Law Should Care*, 97 J. PAT. & TRADEMARK OFF. SOC'Y 597 (2015).

areas of technology while technology is itself becoming more-and-more interdisciplinary.

Finally, I discuss potential reforms that could help the Patent Office respond to changes in innovation practice, and help minimize the number of bad patents that are granted. These include adding nuance to the manner in which examiners are credited for examining particularly complex patent applications, providing a framework for the team assessment of interdisciplinary inventions, opening up the *inter partes* review process to provide more incentives for third parties to participate in identifying potentially invalid patents, and proposing changes to the analogous art doctrine that would alter the bounds of patentability to more accurately reflect changes to the way innovation occurs in the 21st century.

II. PATENT LAW BACKGROUND

A. From Greece to the Statute of Monopolies

The practice of offering the state-sanctioned monopolies that we recognize as patents is a custom that can be traced back at least hundreds, and potentially thousands of years. In the Greek city of Sybaris by 500 BCE "encouragement was held out to all who should discover any new refinement in luxury, the profits arising from which were secured to the inventor by patent for the space of a year."[2] The notion of this system would be instantly recognizable to a modern-day patent law practitioner. Just as is done today, in order to provide incentive for the creation of new luxuries the state guaranteed an exclusive right in the profits to the inventor.

In the 15th century, the Republic of Venice became home to the first organized large-scale patent system.[3] This system granted 10 years of exclusive rights to those who invented "new arts and machines."[4] As Venetian tradesmen, scientists, inventors and merchants moved across Europe, they brought demand for similar state-sanctioned protections for their innovations to their new homes.[5]

2. CHARLES ANTHON, A CLASSICAL DICTIONARY: CONTAINING AN ACCOUNT OF THE PRINCIPAL PROPER NAMES MENTIONED IN ANCIENT AUTHORS, AND INTENDED TO ELUCIDATE ALL THE IMPORTANT POINTS CONNECTED WITH THE GEOGRAPHY, HISTORY, BIOGRAPHY, MYTHOLOGY, AND FINE ARTS OF THE GREEKS AND ROMANS: TOGETHER WITH AN ACCOUNT OF COINS, WEIGHTS, AND MEASURES: *WITH TABULAR VALUES OF THE SAME* 1273 (Harper & Bros. 1872).

3. E. Wyndham Hulme, *History of the Patent System Under the Prerogative and At Common Law A Sequel*, 16 L. Q. REV. 44 n.1 (1900).

4. Ramon A. Klitzke, *Historical Background of the English Patent Law*, 41 J. PAT. OFF. SOC'Y 615, 619 (1959).

5. *Id.*

The English patent law that would eventually inspire patent law in the new world began during Queen Elizabeth's reign.[6] A joint English-Italian team submitted an application for an exclusive patent on a dredging machine in 1558, the first year of Elizabeth's rule. After formal procedures were established for patent grants in 1561, their petition was granted as a reward for the applicant's work and to provide an incentive for others to pursue similar efforts. These patents brought profits not only to inventors, but also to the Monarchy as the crown shared in revenues from monopolized products.

This arrangement eventually led to charges of corruption as the crown began to grant monopolies over common everyday commodities instead of novel innovations.[7] In 1624, King James responded to discontent surrounding the existing patent framework by reforming the system.[8] The reforms contained in the Statute of Monopolies limited patent duration to 14 years, and perhaps even more importantly, allowed patents to be challenged in common law courts. This second aspect of the reform fundamentally altered patents, transforming them from unchallengeable royal decree to a product of common law about which courts could develop a body of case law and establish doctrine. Following the passage of the Statute of Monopolies it took over a century for the courts to establish a reasonably complete set of legal doctrine.[9]

In Elizabethan England, prior to the Statute of Monopolies, patents were available for "inventions." However, the term "invention" at the time included not only what we would now consider an invention, but also the discovery of a process or product already in use outside of England.[10] So, it is difficult to determine how many early English patents were granted for actual novel inventions, and how many were granted for importing inventions from abroad. Indeed, the Elizabethan definition of "novelty" was substantially different from that in use today. At the time, a patent petitioner only needed to demonstrate that the industry in question had not been active within the realm for a reasonable period of time.[11] This is starkly different from the modern definition of novelty which disallows a patent if the invention was available to the public before the application.[12] Although this

6. P.J. Federico, *Origin and Early History of Patents*, 11 J. PAT. OFF. SOC'Y 292, 296 (1929).
7. Klitzke, *supra* note 4, at 640.
8. *Id.* at 649.
9. Adam Mossoff, *Rethinking the Development of Patents: An Intellectual History, 1550–1800*, 52 HASTINGS L.J. 1255, 1276 (2001).
10. Klitzke, *supra* note 4, at 635.
11. *Id.* at 638.
12. 35 U.S.C. § 102 (2016).

understanding of "novelty" might seem perplexing to a modern-day patent law practitioner, it reflects the reality of innovation at the time. Prior to the relatively unconstrained flow of ideas and information that we enjoy today, the act of identifying, importing, and applying foreign ideas was sufficiently costly to justify providing formal incentives for industrialists to do so.

In assessing applications for patents, the Elizabethan system required that there be benefits for the public as a result of granting the patent. This could involve a number of requirements from the patentee including requiring: (1) native apprentices be taught the art; (2) disclosure of the art's secrets; (3) working of the invention within a specified time period; and (4) rents paid to the Crown.[13] The first of these was often exacted, while the latter three were less frequently required.

In its early years, the passage of the Statute of Monopolies did little to alter the manner in which patents were assessed. Applicants still needed to petition the King in hopes of attaining a patent over their inventions.[14] These early patents, much like the Elizabethan ones, were granted to encourage the introduction or establishment of new industries. The Statute of Monopolies created seven conditions for a valid patent grant:

> (i) it must be for less than twenty-one years, (ii) it must be granted to the first and true inventor, (iii) it must be for manufactures not in use at the time of the grant, (iv) it must not be contrary to law, (v) it must not result in the raising of prices, (vi) it must not hurt trade, and (vii) it must not be generally inconvenient.[15]

While the Statute of Monopolies initially did little to alter the details of the patent system, as the courts began to exercise their newfound jurisdiction over the legal scope of patents, patent granting began to evolve. By the 19th century patents were limited to grants over what we would now consider discrete inventions, the courts required written descriptions disclosing the invention to the public, and patents would be held invalid if they were not novel.[16]

This novelty requirement is very similar to that still in force in jurisdictions across the world. We generally do not want to provide patent

13. Klitzke, *supra* note 4, at 639.
14. Federico, *supra* note 6, at 303–04.
15. Mossoff, *supra* note 9, at 1273.
16. Federico, *supra* note 6, at 305.

protection for inventions that already exist. The distinction between novelty judgments in 19th century patent assessment and 21st century patent assessment lies in how difficult it is to determine whether or not a given invention is novel. In the late 18th century in England, the crown was granting only a handful of patents per year.[17] As the industrial revolution began, the trend in English patenting changed, with more and more patents granted every year. However, even by the middle of the 19th century the number of annual patents granted was still on the order of hundreds, rather than the hundreds of thousands that we see today. This left those charged with examining applications with a comparatively small and manageable body of prior art to search through and be familiar with as they determined whether or not an invention was sufficiently novel.

This very brief history of early patent law demonstrates how it has evolved, changing pragmatically over time to respond to political realities, economic changes, and changes in the way innovation occurs. Following its adoption of a patent law system similar to that in existence in England during the time of the revolution, the development of the American patent system tells a similar story of adaptation over time.

B. Patent Law in the United States

The history of the United States Patent Office is marked by its dramatic growth and evolution in response to changes in the American economy and the way innovation occurs. As it changed from a registration only system, to a small office granting a few dozen patents per year, to the large entity now employing thousands of examiners granting hundreds of thousands of patents per year, the Patent Office has always had to evolve in order to successfully fulfill its mission.

1. The 19th Century Growth in Patenting

The 18th and 19th century patenting trend in the United States largely mirrors that experienced in England. Between the foundation of the United States and 1836 when the patent numbering system that we still use originated, there were approximately 9,957 patents issued. Subsequently, the USPTO granted on the order of hundreds or a few thousand patents per year until the mid-19th century.[18] This relatively small number of patents meant that being familiar with the state of the art was within the capabilities of a

17. *See* Richard J. Sullivan, *England's "Age of Invention": The Acceleration of Patents and Patentable Invention during the Industrial Revolution*, 26 EXPLORATIONS ECON. HIST. 424, 444 (1989).

18. U.S. PAT. & TRADEMARK OFF., TABLE OF ISSUE YEARS AND PATENT NUMBERS, FOR SELECTED DOCUMENT TYPES ISSUED SINCE 1836, https://www.uspto.gov/web/offices/ac/ido/oeip/taf/issuyear.htm.

human patent examiner. When an application was made, examiners were able to determine with a relatively manageable amount of research whether or not it claimed a truly novel invention, or whether similar technologies already existed. By the mid-19th century, as the industrial revolution began to transform technology, the task of application assessment became much more complex.

The Industrial Revolution dramatically changed both technology and the work of the Patent Office. By the end of the 19th century, the USPTO was granting tens of thousands of patents per year. In total, by 1900 the USA had granted over 600,000 utility patents.[19] This obviously left a much larger body of prior art for both inventors and examiners to deal with. In the 18th century, when the number of patents granted per year was often less than a dozen, it was relatively easy to determine whether a patent had been granted in a particular area before. In addition, when the scope of industrial technology was relatively limited, it was comparatively easy for examiners to become familiar enough with the technology in question that they were able to distinguish between novel contributions and claims for inventions that already existed.

These changes in the innovation system were accompanied by evolution in the way that the United States examined (or at times did not examine) applications for a patent. Under the Patent Act of 1793, the United States used a registration rather than an examination system.[20] This put it in line with the contemporary British system. Under a registration system, an inventor simply needed to register his invention and attest that he was the inventor and that it was patentable. This was sufficient to allow for patent protection. Eventually, this system came under criticism for being overly permissive, and was altered by the creation of the Patent Office in 1836.[21] The examiners that worked in this early Patent Office were quite different in kind than those employed by the Office today.

2. Early Patent Examiners

The structure of the early Patent Office and its examination process is a product of the innovation system it was established to regulate. Initially it

19. U.S. PAT. & TRADEMARK OFF., U.S. PATENT STATISTICS CHART CALENDAR YEARS 1963–2015 (2015), http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm.

20. Edward C. Walterscheid, *Novelty in Historical Perspective (Part II)*, 75 J. PAT. & TRADEMARK OFF. SOC'Y 777, 786 (1993).

21. Robert C. Post, *Liberalizers" versus "Scientific Men" in the Antebellum Patent Office*, 17 TECH. & CULTURE 24, 28 n.12 (1976); GUSTAVUS ADOLPHUS WEBER, THE PATENT OFFICE, ITS HISTORY, ACTIVITIES AND ORGANIZATION, 11 (John Hopkins Press 1924).

was a very small office, employing only two examiners by the end of 1838,[22] demonstrating the comparatively low demand for patents at the time. In early years the number of examiners grew quite slowly increasing to four in 1848 and a dozen by 1861.[23] These early examiners were generalists. According to Senator Ruggles—one of the contemporary politicians most active in patent reform—examiners were a rare breed, because:

> An efficient and just discharge of the duties, it is obvious, requires extensive scientific attainments, and a general knowledge of the arts, manufactures, and the mechanism used in every branch of business in which improvements are sought to be patented, and of the principles embraced in the ten thousand inventions [already] patented in the United States, and of the thirty thousand patented in Europe. He must moreover possess a familiar knowledge of the statute and common law on the subject, and the judicial decisions both in England and our own country, in patent cases.[24]

This reflects the degree of expertise that individual examiners were expected to have at the time. These individuals were not simply domain experts in a particular field, they had general scientific knowledge and were considered equipped to assess a patent application in any technical area. These examiners were expected to be a "living encyclopedia of science."[25] As a result, by the mid-19th century, the patent office had "perhaps the best assembly of physics and engineering brainpower under one roof anywhere in the country."[26]

These encyclopedic examiners were a product of an innovation system that was remarkably simpler than the one that exists today. In 1836 a single examiner was considered capable of assessing *any* patent application either by way of their already broad expertise, or because they would be able to single-handedly use the patent office's quickly growing library to perform the requisite research and assess patentability.[27] This would be unimaginable in today's innovation system. The growing size and complexity of the

22. U.S. PAT. & TRADEMARK OFF., *Annual Report of the Commissioner of Patents for 1838* (1838).
23. Post, *supra* note 21.
24. *Id.* at 28.
25. *Id.* at 33.
26. *Id.* at 38.
27. *Id.* at 39.

knowledge space has led to the "death of the renaissance man"[28] as no single individual could possibly have a breadth of knowledge sufficient to be an expert in every technical field. Even with the improved research capabilities we now have, science and technology have become so complex that without sufficient training and expertise in the discipline in question, a generalist cannot hope to be able to adequately assess the patentability of inventions in every conceivable technical area. This growth in technical complexity led not only to more patent examiners, but also changes in the way information was stored and categorized at the Patent Office.

3. The Patent Classification System

The historical development of the patent office's technology classification system provides a record of the increasing complexity confronting examiners. Initially, under the registration regime, patents were unclassified. It was not until an 1830 report about the state of the patent system that the office added some structure to the data representing the patents they had granted by classifying them into six categories.[29] The number of categories grew from six to 22 when the examination system began in 1836, 36 by the time there were around 80,000 patents in 1868, and 226 in 1897, the year before the Patent Office founded a permanent division to maintain its classification system.[30] The classification division has the difficult task of attempting to comprehensively categorize all technical knowledge, and keep this categorization scheme up to date as new technologies emerge. Some describe this unit's work as "probably the most involved in the Patent Office."[31]

Today there are hundreds of main patent classes, each with dozens or hundreds of subclasses.[32] This steady increase in the specificity of the USPC scheme is a response to the increasing complexity of technical knowledge. As more and more knowledge is generated, and it becomes more specific and complex, examiners require more categories to sort the technology into in order to make application assessment tenable. By the 1920s the Patent Office library contained records on millions of domestic and foreign patents.[33]

28. Benjamin F. Jones, *The Burden of Knowledge and the "Death of the Renaissance Man": Is Innovation Getting Harder?*, 76 REV. ECON. STUD. 283, 308 (2009).

29. WEBER, *supra* note 21, at 19.

30. *Id.* at 18–19.

31. *Id.* at 65.

32. U.S. PAT. & TRADEMARK OFF., US CLASSES BY NUMBER WITH TITLE (2016), http://www.uspto.gov/web/patents/classification/selectnumwithtitle.htm.

33. WEBER, *supra* note 21, at 70.

Without the classification system—especially before the development of full text search capabilities—examiners would have been unable to compare the application to the state of the art.[34]

As the classification system grew in complexity, and the number of examiners grew to meet the increasing size and complexity of the innovation knowledge space, the Patent Office also began to organize itself into assessment groups with particular areas of expertise. As of 1924, patent examiners were organized into 49 distinct technological areas, each responsible for examining applications claiming inventions within their areas of expertise.[35] These examining divisions are now referred to as "art units" and are organized under 9 "technology centers."[36] The technology centers are comprised of 2,171 art units,[37] staffed by over 9,000 patent examiners.[38]

4. The Patent Office Today

The overarching trend since the Patent Office's inception has been towards increased specialization. We see a move from generalist examiners to those with increasingly narrow but deep expertise in a specific technical area, and a concomitant increase in the number of examiners. Meanwhile, in response to the growing information universe, we also see an increasingly complex patent classification scheme and an ever-growing set of art units. This ever-increasing specialization largely mirrors what we observe in the world of research more generally. As the amount of knowledge researchers must navigate increases, the "burden of knowledge" becomes too large for generalist expertise.[39]

However, there is an important distinction between the specialization we observe within the Patent Office and that which we see in the research

34. *Id.* at 37.

35. *Id.* at 62.

36. U.S. PAT. & TRADEMARK OFF., PATENT TECHNOLOGY CENTERS (2010), http://www.uspto.gov/about/contacts/phone_directory/pat_tech/ (The current Technology Centers are: Biotechnology and Organic Chemistry; Chemical and Materials Engineering; Computer Architecture, Software, and Information Security; Computer networks, Multiplex Communication, Video Distribution, and Security; Communications; Semiconductors, Electrical and Optical Systems and Components; Designs; Transportation, Construction, Electronic Commerce, Agriculture, National Security and License & Review; Mechanical Engineering, Manufacturing, Products).

37. U.S. PAT. & TRADEMARK OFF., OFFICE PATENT CLASSIFICATION, PATENT CLASSIFICATION: CLASSES ARRANGED BY ART UNIT, TEXT (2016), http://www.uspto.gov/patents-application-process/patent-search/understanding-patent-classifications/patent-classification.

38. U.S. PAT. & TRADEMARK OFF., TECHNOLOGY CENTER LEVEL DATA (2017), http://www.uspto.gov/sites/default/files/tcleveldashboard.xlsx (last accessed Sept. 1, 2017).

39. Jones, *supra* note 28, at 308.

world. In response to knowledge complexity, researchers have increasingly begun to organize into teams, where dispersed expertise allows them to be more effective as a collective.[40] These teams have become more-and-more multi-disciplinary as the benefits of drawing on multiple areas of knowledge have become clear.[41] While there is some semblance of teamwork at the Patent Office, the vast majority of an examiner's work is solitary in nature, and there are rarely opportunities for collaboration across specializations.

When an inventor submits a patent application to the USPTO it is not randomly assigned to an examiner. Rather, an initial examiner will assign the application to a technology center.[42] The examiners are organized into specialized "art units" that are responsible for examining applications within a specific subset of technology classes associated with these technology centers.[43] Examiners within each art unit specialize in the technologies that their unit is responsible for.

This sort of specialization has many advantages. When dealing with complicated and cutting-edge technologies, the domain expertise that patent examiners accrue by focusing on one area of technology allows them to more efficiently do their job. The first step that examiners take in the examination process is to read and understand the claimed invention. This is obviously made easier when the examiner is an expert in the field.

After initially reading and considering an application, the examiner engages in a prior art search that surveys the stock of existing knowledge to determine whether the claimed invention is patentable.[44] When searching the prior art, the examiner looks not only to prior art within the same field as the claimed invention, but also within analogous fields.[45] Specialized knowledge assists this prior art search allowing examiners to more quickly determine how relevant a piece of prior art is and whether it raises patentability issues.

Specialization at the USPTO helps it efficiently perform its role. Without expertise in the technology areas they work within, examining patent applications would take longer, and would likely also have a higher error rate. However, despite its efficient tendencies, specialization runs into

40. *Id.*; Stefan Wuchty et al., *The Increasing Dominance of Teams in Production of Knowledge*, 316 SCI. 1036, 1037 (2007).

41. *See generally* Stephen M. Fiore, *Interdisciplinarity as Teamwork How the Science of Teams Can Inform Team Science*, 39 SMALL GROUP RES. 251 (2008); *see also* MICHAEL GIBBONS ET AL., THE NEW PRODUCTION OF KNOWLEDGE: THE DYNAMICS OF SCIENCE AND RESEARCH IN CONTEMPORARY SOCIETIES (Sage 1994).

42. U.S. PAT. & TRADEMARK OFF., MANUAL OF PATENT EXAMINING PROCEDURE § 903.08(a) (9th ed. 2015) [hereinafter MPEP].

43. MPEP § 903.08(b).

44. MPEP § 904.

45. MPEP § 904.01(c).

problems when individuals are forced to deal with technologies outside their area of specialization and when the areas of specialization are subject to change.

When an examiner is assigned an application claiming an invention somewhat outside her area of expertise, the examination process is bound to become more difficult. Thus, their ability to efficiently examine applications depends largely on the correct categorization of incoming patent applications. If a patent is miscategorized or implicates diverse knowledge and therefore spans multiple categories, the strengths of specialization may become weaknesses.

When this happens, the MPEP has rules intended to remedy the lack of expertise. Each Patent Office technology center has procedures in place to reassign an application from one art unit to another among the units the center manages.[46] There is also a method to transfer applications between different technology centers, if the supervisory patent examiner believes they are misclassified.[47] These procedures help ensure that applications are examined by individual with relevant expertise.

Although procedures to transfer technologies between art units or technology centers help alleviate challenges that arise from specialization, they do not completely ameliorate the underlying problem. Technologies often span technological boundaries, implicating a variety of USPTO technology classes.[48] When this occurs the USPTO is hampered by its silo-like structure. Focusing on discrete technological areas means that examiners are less-well-equipped to deal with inventions that span technological boundaries. They will be less familiar with prior art outside of their area of expertise, and less able to assess an invention's merits.

The next section will empirically demonstrate how, while the patent examination practice has continued to focus on solitary specialization, the reality of the innovation process has tended towards increased collaboration and knowledge diversity.

III. THE EVOLUTION OF INNOVATION

The above has sketched out the institutional evolution of the Patent Office as it has responded to the increasing size and complexity of the knowledge space. While the Patent Office was increasing the size of its examination corps, employing more specialized examiners, structuring

46. MPEP § 903.08(d)(I).

47. MPEP § 903.08(d)(II).

48. *See* Hyejin Youn et al., *Invention as a Combinatorial Process: Evidence from US Patents,* 12 J. ROYAL SOC'Y INTERFACE 20150272, 3 (2015).

examiners into expert groups, and building and maintaining a thorough invention classification scheme, the way innovators do their work has also evolved. In many ways, the changes we see in the way innovators work are similar to those patent examiners were undergoing. Innovators are now less likely to be generalists, instead choosing to work in more-and-more narrowly-focused areas of science and technology.[49] However, the innovation system has also evolved in a variety of ways that are distinct from the changes at the Patent Office. The increased tendency towards collaboration and interdisciplinary have fundamentally changed the way invention occurs. The Patent Office has yet to respond adequately to these changes, raising concerns about its ability to adequately assess patentability. This section will empirically demonstrate these changes to the way innovation occurs, before the next section discusses potential reforms at the Patent Office that could help it prepare to assess 21st century innovation.

A. Increasing Size of the Knowledge Space

Growth in the amount of information available to researchers is perhaps the most important factor influencing the way innovation occurs. To understand why this is the case, it is useful to conceptualize innovation work as information work. One of the primary tasks researchers engage in, is the recombination of pieces of knowledge to assemble new and useful wholes.[50] In doing so, researchers draw on existing information as they create new information. This generates an ever-increasing amount of information, as new inventions and scientific and technical discoveries all add to the body of pre-existing knowledge that inventors can draw upon.

We can clearly see this growth in the amount of available information by looking to the number of patents granted, or journal articles published. For instance, if we plot over time the number of patents eligible to be cited as prior art, we see not only the linear growth we might expect, but a curvilinear increase, as the number of patents granted per year has increased relatively steadily over time (see Figure 1). The same is true of scientific journal articles as more and more journals publish more and more scientific articles.[51] This exponential growth in the amount of available knowledge[52]

49. *See generally* Jones, *supra* note 28.

50. *See generally* Martin L. Weitzman, *Recombinant Growth*, 113 Q.J. ECON. 331 (1998); Lee Fleming, *Recombinant Uncertainty in Technological Search*, 47 MGMT. SCI. 117 (2001).

51. *See generally* Arif E. Jinha, *Article 50 Million: An Estimate of the Number of Scholarly Articles in Existence*, 23 LEARNED PUB. 258 (2010); Michael Mabe & Mayur Amin, *Growth Dynamics of Scholarly and Scientific Journals*, 51 SCIENTOMETRICS 147 (2001).

52. *See generally* DEREK DE SOLLA PRICE, LITTLE SCIENCE, BIG SCIENCE . . . AND BEYOND (Colum. U. Press 1986).

makes an exhaustive search of the knowledge space more-and-more difficult every year.

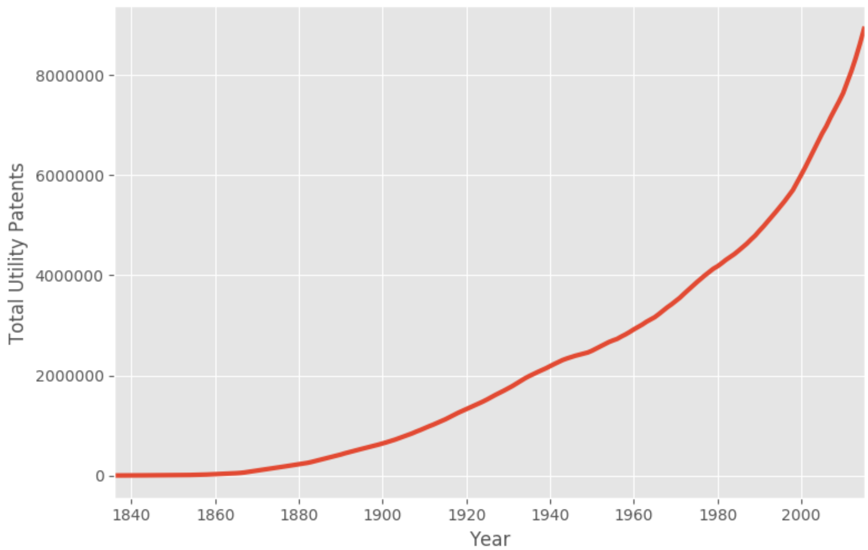

FIGURE 1: Total number of current and expired utility patents in existence at the beginning of each year.

As the amount of available information increases, it becomes more difficult to generate new inventions, requiring greater investment for each generated invention.[53] Furthermore, a larger knowledge space makes it more difficult to assess novelty when a purportedly "new" invention is claimed. As examiners are required to search more-and-more prior art for technologies relating to those claimed in a patent application, the difficulty of their task steadily increases, leading to potentially higher error rates or examinations that demand more time.

B. The Rise of Teamwork

One of the clearest differences between the changes experienced by innovators and those adopted by the patent office has been the steady

53. *See* Samuel S. Kortum, *Research, Patenting, and Technological Change*, 65 ECONOMETRICA 1389, 1392 (1997).

increase in the prevalence and importance of team research.[54] The increasing size and complexity of the knowledge space is one of the primary factors driving this move towards increased collaboration.[55] While teamwork has steadily increased outside of the Patent Office, patent examination remains a primarily individual task, completed by an examiner whose work is then reviewed by a supervisor.[56]

The patent data provides a clear empirical demonstration of how team research has become more common in recent decades.[57] Figure 2 graphs the average number of inventors per patent from 1976 to 2014. We see a steady increase in the number of inventors attributed to each invention as teamwork becomes more-and-more common.

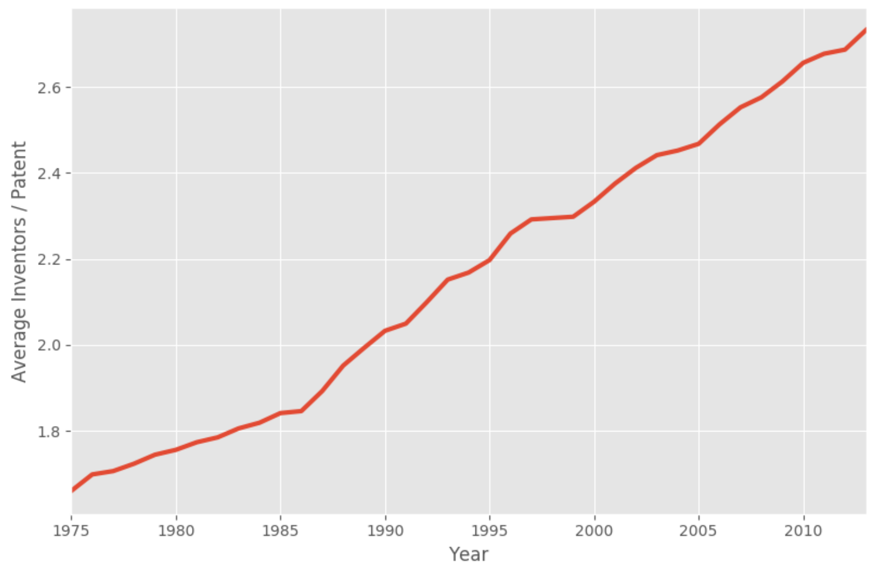

FIGURE 2: Mean number of inventors per patent.

While the evidence in Figure 2 strongly suggests an increasing trend towards collaboration, the same results could also arise from increasing *size* of collaborative teams. If teams are growing in size, then we could see an

54. *See generally* Wuchty, *supra* note 40.
55. Jones, *supra* note 28, at 283.
56. *See* MPEP §§ 702, 705.01(b) 700–724.06.
57. The below figures are derived from publicly-available patent data provided by the USPTO. *See generally* U.S. PAT. & TRADEMARK OFF., UNITED STATES PATENT & TRADEMARK OFFICE PATENT FULL-TEXT/APS, https://www.uspto.gov/sites/default/files/products/PatentFullTextAPSGreenBook-Documentation.pdf.

increase in the average team size, without actually seeing an increase in collaborative versus individual invention. To address this, we can graph the rate of collaboration over time. Figure 3 shows the proportion of inventions each year that were invented by more than one individual. Here we see a steady increase in how common it is for a patent to list more than one inventor, with the collaboration rate increasing by almost thirty percentage points since 1975.

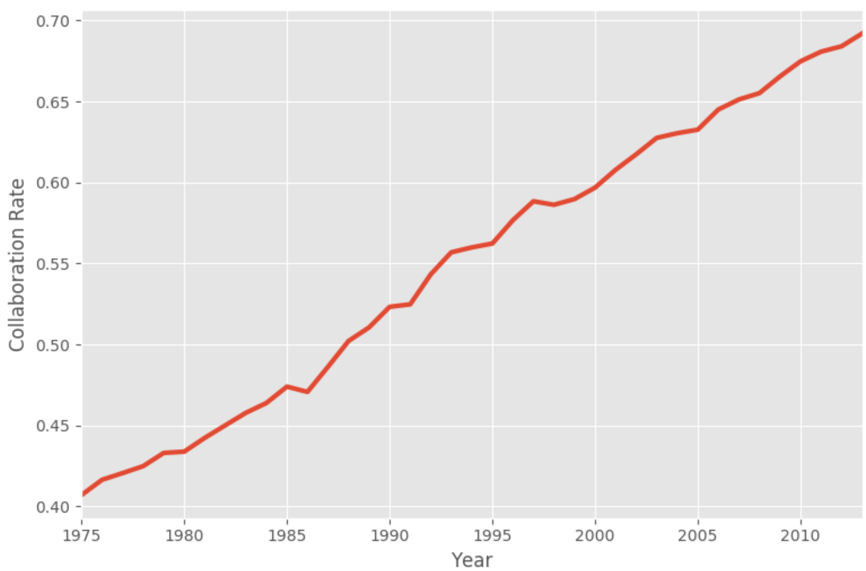

FIGURE 3: Proportion of granted utility patents listing two or more inventors.

So, we see that both the average team size and the rate of collaboration are steadily increasing. Furthermore, in addition to becoming more prevalent in the way innovators do their work, teamwork is also becoming more important as it more often leads to the most influential inventions and scientific and technical advances. Research shows that a collaboratively created invention has a significantly higher probability of going on to have high future impact[58] and that particularly large teams also tend to create more influential inventions.[59] This suggests that the ability to accurately assess the patentability of inventions generated by teams is particularly important, as

58. *See generally* Wuchty, *supra* note 40.

59. *See, e.g.*, Anthony Breitzman & Patrick Thomas, *Inventor Team Size as a Predictor of the Future Citation Impact of Patents*, 103 SCIENTOMETRICS 631, 632 (2015).

society has an interest in ensuring that we have efficient incentives to create high impact inventions.

C. Increasing Combinatorial Complexity

Along with, and related to, the growing size of the knowledge space and the increasing importance of collaboration we have observed in recent decades, we have also seen more complexity in the way knowledge is recombined. This increasing complexity makes the patent examination task more difficult as examiners need to be familiar with, or at least conversant in, more areas of knowledge in order to assess these complex inventions. Using a variety of measures from the patent granting record, this section will empirically demonstrate how technological complexity has steadily increased in recent decades.

One way to consider the complexity of a new invention is to look at its combination of information antecedents. For instance, this can be done in the context of journal articles by looking to the publication venue and classifying them according to their scientific field,[60] or when dealing with patents it can be done by looking to the combination of technology classes cited,[61] or the combination of classes assigned to the patent by the Patent Office.[62]

Youn and colleagues clearly demonstrate the increasing complexity of inventions by charting the novelty of their technology class combinations.[63] They show both that the size of the technological search space has steadily increased, and that inventions introduce a new combination of technologies approximately 60% of the time.[64] This high degree of novelty is perhaps unsurprising, given that novelty is one of the statutory patentability requirements.[65] However, it means that the technological system is in a constant state of change, making the task of staying abreast of the technological bleeding edge more challenging than it would be in a more slowly evolving system.

In addition to looking at technology classification combinations as a measure of complexity, we can also look to prior art citations. These citations provide a record of how a new technology builds on existing knowledge.

60. Brian Uzzi et al., *Atypical Combinations and Scientific Impact*, 342 SCI. 468, 468–469 (2013).

61. Fleming, *supra* note 51, at 122; You-Na Lee et al., *Creativity in Scientific Teams: Unpacking Novelty and Impact*, 44 RES. POL'Y 684, 688–689 (2015).

62. Youn, *supra* note 49, at 3–4.

63. *Id.* at 3–4.

64. *Id.* at 3–4.

65. 35 U.S.C. § 102(a) (2015).

Citation records empirically demonstrate the ever-increasing complexity of the innovation system in a variety of ways.

1. Number of citations.

Perhaps the simplest way that prior art references demonstrate the growth in complexity is in their increasing number. The average patent today makes many more citations to prior art than the average patent of three decades ago. Figure 4 plots this growth over time. This suggests that these inventions implicate more preexisting technologies blended together into a new whole. By drawing on more pieces of knowledge and thus creating a more intricate mixture of information, these inventions will likely result in greater difficulty of assessments of novelty and nonobviousness for examiners.

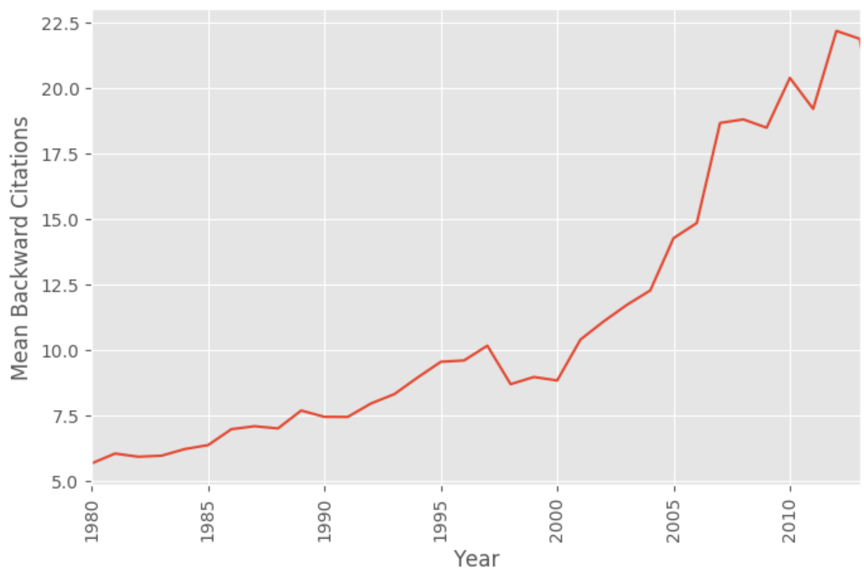

FIGURE 4: Mean number of prior art citations from granted utility patents to other utility patents.

2. Increasing knowledge translation.

Another way to consider the changing degree of complexity in the innovation system is looking to the degree to which the average new invention translates knowledge from a distant field. An invention drawing only on knowledge directly within its specialization area is comparatively less complex, as it makes a smaller, more incremental, step in the evolutionary process of knowledge development. On the other hand, an invention that translates very distant knowledge, takes a greater step generating an invention that is less similar to technologies we are already familiar with.

We can measure knowledge translation by examining how inventions draw on knowledge, and how "distant" it is from their own field. For instance, an invention for a new coffee grinder that integrates elements already present in a blade-style and burr-style grinders will draw on relatively proximate knowledge. It is likely to represent an incremental improvement to the state of coffee grinding technology. As such, an individual familiar with the state of the coffee grinding art is likely to be well-equipped to assess the degree to which it is both novel and nonobvious. On the other side of the spectrum is a coffee grinder that draws on highly distant knowledge. For example, consider a grinder invention that translates a new development in the world of boring machines used in the mining industry by adapting it for coffee grinding uses. This represents the translation of comparatively distant knowledge, and likely a greater step in the progression of coffee grinding technologies. As such, its importance may be more difficult to assess. To adequately understand the invention, one would ideally not only be familiar with the state of the art in coffee grinding technologies, but also the state of the art in boring machines.[66]

We can empirically test for this by comparing patents with the patents they cite as prior art. Patent citations express relationships between a patent and the "prior art" that it is related to. These citations express relationships between technologies, and can demonstrate how one technology builds upon another, or relatedly can act as a disclaimer ensuring that newly granted patents do not retain rights over pre-existing intellectual property.[67] These prior art citations were originally included in order to assist examination searches, allowing examiners to more efficiently determine the state of the art.[68] In addition to their intended use, researchers have capitalized on prior art citations using them as proxy measures for the value of the underlying invention,[69] the magnitude of the technological improvement made by the

66. By definition, a boring area of expertise.

67. Martin Meyer, *What is Special About Patent Citations? Differences Between Scientific and Patent Citations*, 49 SCIENTOMETRICS 93, 98 (2000).

68. Harry C. Hart, *Re: Citation System for Patent Office*, 31 J. PAT. & TRADEMARK OFF. SOC'Y 714, 714 (1949); Arthur H. Seidel, *Citation System for Patent Office*, 31 J. PAT. OFF. SOC'Y 554, 554 (1949).

69. *See* Michael B. Albert et al., *Direct Validation of Citation Counts as Indicators of Industrially Important Patents*, 20 RES. POL'Y 251 (1991); *see also* James Bessen, *The Value of US Patents by Owner and Patent Characteristics*, 37 RES. POL'Y 932 (2008); *see generally* Manuel Trajtenberg, *A Penny for Your Quotes: Patent Citations and the Value of Innovations*, RAND J. ECON. 172 (1990).

cited patent,[70] the market value of the patent-owning firm,[71] and the flow of knowledge between individuals and across geography.[72]

We can use natural language processing techniques to compare the content of citing and cited patents. One of the conditions for receiving a patent is publication of a description of the invention and the legal claims the inventor makes. Using the text within these publications—which is available in machine readable form from 1976 on—we can compare inventions to their cited prior art and measure how similar or dissimilar they are from one another.

There are a variety of methods available to compare textual similarity.[73] Here I use the well-established latent semantic analysis (LSA) method, which allows us to compare the text of many publications and detect latent similarities between them.[74] One of the strengths of this method is that it does not rely on authors to use exactly the same terminology in referring to similar concepts or ideas, but is able to detect latent similarities in words used in similar contexts (e.g., car and automobile) and treat them as semantically similar.

Using the full text of all patents granted from 1976 to 2014, I first generate a latent semantic model and subsequently use that model to locate each patent within this highly-dimensional semantic space. After determining the coordinates of each patent, I can then measure their "distance" from one another by calculating the cosine of the angle between their LSA vectors.[75] This measure provides a "distance" score representing dissimilarity between patents. I then use these scores to weight the citations between patents and their prior art.

These semantic distance scores reflect the degree to which an invention has translated distant knowledge. So, in the context of the coffee grinder examples raised above, we would expect to see our combination burr/blade

70. *See* Kristina B. Dahlin & Dean M. Behrens, *When is an Invention Really Radical?: Defining and Measuring Technological Radicalness*, 34 RES. POL'Y 717 (2005); *see also* Petra Moser et al., *Patent Citations and the Size of the Inventive Step - Evidence from Hybrid Corn*, SSRN Scholarly Paper ID 2641659 (Social Science Research Network), Jul. 1, 2015.

71. *See* Bronwyn H. Hall et al., *Market Value and Patent Citations*, RAND J. ECON. 16, 16–17 (2005).

72. *See generally* Juan Alcácer & Michelle Gittelman, *Patent Citations as a Measure of Knowledge Flows: The Influence of Examiner Citations*, 88 REV. ECON. & STAT. 774 (2006); Olav Sorenson et al., *Complexity, Networks and Knowledge Flow*, 35 RES. POL'Y 994 (2006).

73. *See* Sébastien Harispe et al., *Semantic Similarity from Natural Language and Ontology Analysis*, 8 SYNTHESIS LECTURES ON HUM. LANGUAGE TECH. 1, 53 (2015).

74. *See, e.g.*, Scott C. Deerwester et al., *Indexing by Latent Semantic Analysis*, 41 J. AM. SOC'Y INFO. SCI. 391, 391–392 (1990); Thomas K. Landauer et al., *An Introduction to Latent Semantic Analysis*, 25 DISCOURSE PROCESSES 259, 259–60 (1998).

75. Landauer, *supra* note 74, at 259–60.

grinder to have a relatively low score—as the texts of the patents cited would include much similar language and discuss many similar concepts—whereas the boring machine grinder would have a higher score as it cites to patents that contain very different language.

When we track these scores over time, we see that the innovation system has steadily trended towards more distant knowledge translation. Figure 5 shows this trend very clearly, with average backward citation scores increasing monotonically year-on-year for every year in the dataset. This trend is consistent across technological fields as well. When I separate inventions into technological categories, we see that each field has trended upwards in its tendency to translate distant knowledge, and that once distinct fields appear to be converging towards a uniformly high degree of knowledge translation. Figure 6 shows these trends when, based on its primary USPC classification, every patent is assigned to one of six categories.[76]

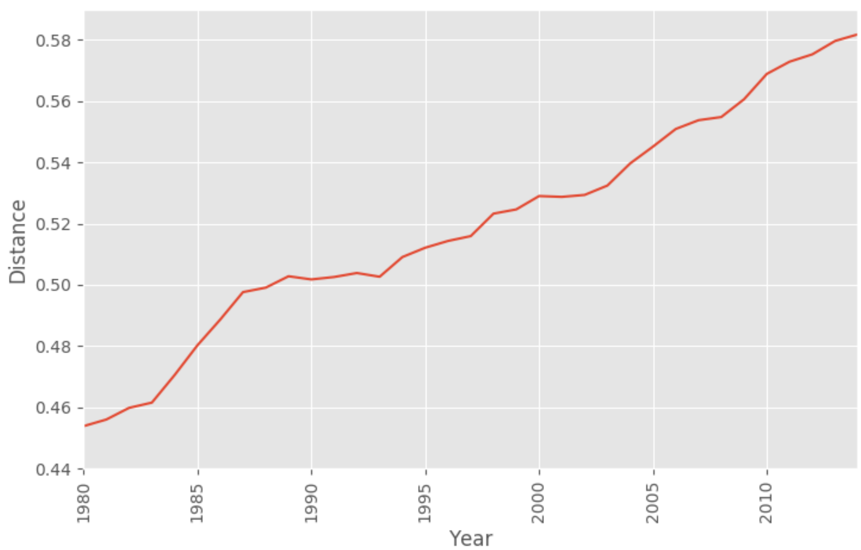

FIGURE 4: Average backward citation distance by year.

76. Bronwyn H. Hall et al., *The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools*, 3 (Nat'l Bureau of Econ. Res. Working Paper 8498, 2001).

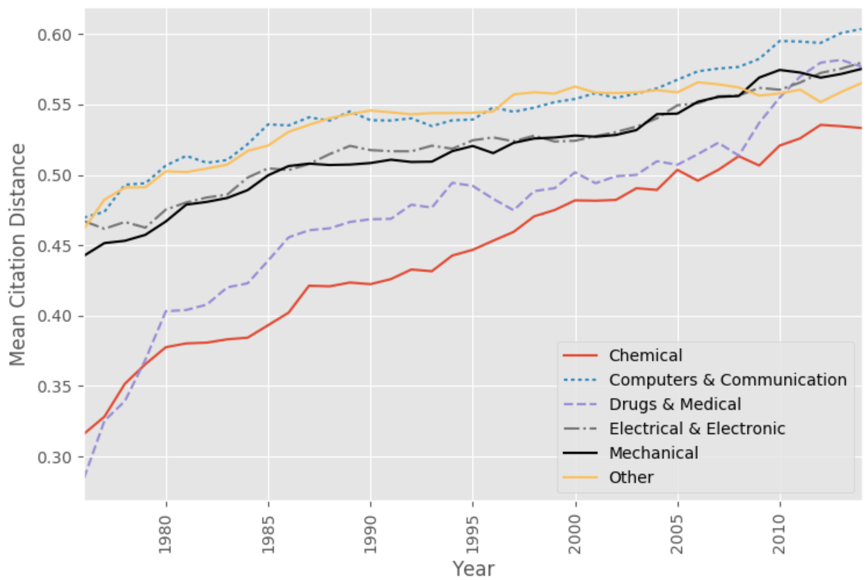

FIGURE 5: Showing mean backward citation distance by technology type.

This steady increase in knowledge translation provides further empirical evidence that the innovation system is growing in its complexity. Inventions are drawing on more-and-more distant ideas. As they do so, understanding and assessing these inventions requires a wider range of knowledge and familiarity with more technical fields.

3. Changes in Knowledge Integration.

In much the same way as we can detect increasing complexity within the innovation system by measuring changes in knowledge translation tendencies, we can also look to the way that inventors combine sets of knowledge, integrating it into a new whole. In this case, we look to the distance between the various prior art inventions cited by a patent. Rather than capturing the degree to which inventors reach across the knowledge space, in search of information from a different field than the one they are inventing in, the knowledge integration measure captures the diversity of information antecedents.

This measure is calculated similarly to the knowledge translation score. We first transform each patent into a series of coordinates in an LSA vector space model.[77] Subsequently, we measure the distance between patents that are co-cited by the same invention. So, if invention *X* cites to previously granted patents *A*, *B*, and *C,* we calculate the distances between *A*–*B*, *B*–*C*, and *A*–*C*. This creates a co-cited network, with links between each of the co-cited inventions. So as not to overweight highly proximate clusters within this network, we then take the minimum spanning tree of the network,[78] which leaves us with a single-component network joined by the least distance—in effect it captures the minimal distance we need to travel in the knowledge space to reach each of the cited inventions.

Both the sum and the maximum of the distance scores in this co-cited network, provide useful insight into how inventors integrate diverse knowledge into their inventions. The sum of these scores represents the total distance between all of the knowledge integrated. However, this total distance score will of course increase along with the number of citations, even if those citations are relatively proximate to one another. The maximum on the other hand, represents the distance between the two most diverse pieces of knowledge integrated within the invention. Figure 7 plots the yearly average for both total and maximum distance between co-cited references. We see a steady increase in each of these measures in recent decades, suggesting that inventions have drawn on more areas of the knowledge space, as well as areas that are more dissimilar to one another.

77. The same model calculated for the knowledge translation measure.

78. *See* Joseph B. Kruskal, *On the Shortest Spanning Subtree of a Graph and the Traveling Salesman Problem*, 7 PROC. AMER. MATH. SOC. 48, 48 (1956).

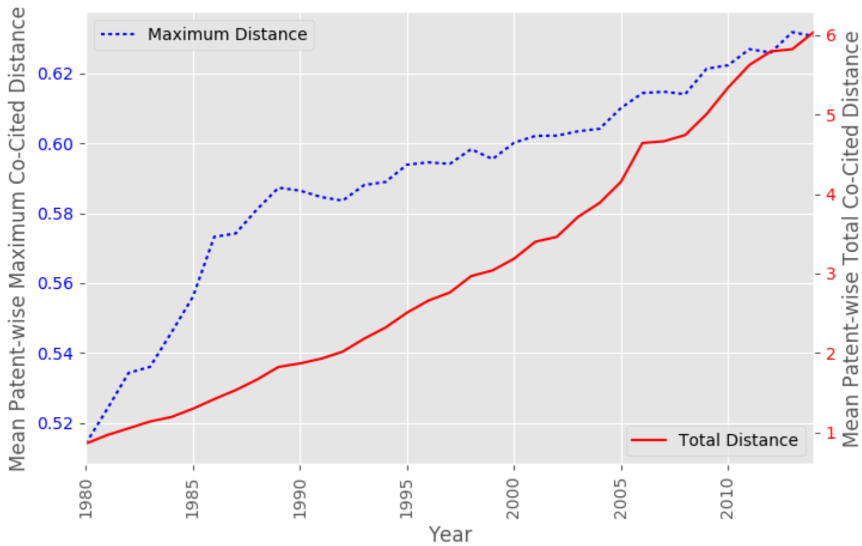

FIGURE 6: Yearly trends for maximum co-cited distance by patent, and total distance between co-cited references by patent.

4. The Rise of Cross-Disciplinary Research

In addition to the above quantitative empirical demonstrations of how innovation has changed in recent decades, we also know from the sociology of science that research has become more interdisciplinary as teams work across traditional disciplinary divides to make new discoveries. Gibbons has famously argued that modern knowledge production has moved from what many of us consider traditional scientific research to a new mode, which is characterized by problem-oriented research and transdisciplinarity.[79] This is echoed by Fiore who argues that interdisciplinary teamwork has arisen because of "the increasing complexity of the types of problems researchers are trying to address."[80]

The "major increases" we have seen in interdisciplinarity[81] pose challenges for a patent office that is structured based on areas of individual expertise. The primary benefit that accrues from interdisciplinarity is an increased ability to mix knowledge from multiple disciplines in novel ways. These new mixtures generate unique research output. In creating these

79. *See generally* Fiore, *supra* note 41.
80. *Id.* at 256.
81. Alan L. Porter & Ismael Rafols, *Is Science Becoming More Interdisciplinary? Measuring and Mapping Six Research Fields over Time*, 81 SCIENTOMETRICS 719, 719 (2009).

mixtures, interdisciplinary research draws on multiple areas of knowledge, making understanding all of the antecedent knowledge inputs difficult for an individual with expertise in only one of the implicated disciplinary areas. As such, the solitary, domain-expert, examiners that the Patent Office relies upon are increasingly at a disadvantage as more and more of the applications they receive are the product of these interdisciplinary research projects. It is difficult for the USPTO to categorize this work—a fact reflected in the dramatic rise of multiple classifications assigned to patents and applications[82]—and even when it is classified it remains difficult for a single individual to have the necessary familiarity with the technical literature and underlying knowledge to be able to adequately assess its patentability.

* * *

The changes to the innovation system in recent decades suggest a growing mismatch between the innovation system that the USPTO is designed to work within and the one it actually does. The next section will explore how the Patent Office and legislators have responded to this mismatch, and demonstrate that, while there have been some initiatives to respond to the growing complexity of the innovation system that the Patent Office must deal with, there is still much room for improvement as the USPTO adapts to 21st century innovation realities.

IV. INNOVATION SYSTEM COMPLEXITY AND THE USPTO

Section III discussed the various ways in which the innovation system is becoming more complex. There has been accelerating growth in the amount of prior art that examiners must contend with. Not only are there ever-more patents to search through, the non-patent literature is also growing in a non-linear fashion.[83] A trend towards more and more prior art citations means that this knowledge is increasingly interconnected. The prior art citations that the USPTO includes were originally included to provide examiners with "a network of paths" to assist them in their prior art searches.[84] This increase in prior art and citations has led to many more paths for examiners to explore before they can be sure their search has been comprehensive. These changes in the amount of information available, and its interrelatedness, raise concerns about potential "deflation in quality" as

82. *See generally* Youn, *supra* note 49.
83. *See* Mabe & Amin, *supra* note 52, at 147–151.
84. *See* Hart, *supra* note 68, at 774.

both examiners and inventors struggle to cope with the ever-growing amount of information they must navigate.[85]

Along with these changes in the scale of the innovation system, there have also been qualitative changes in the way innovation occurs. Innovation has increasingly occurred in teams,[86] and the knowledge that inventions draw upon is increasingly distant and increasingly diverse. These changes in the innovation system pose challenges for the Patent Office. This Section will explore some developments at the Patent Office that have coincided with the increasing size and complexity of the innovation system, and subsequently describe more thoroughly how the Patent Office's 20th century assessment model is mismatched with the 21st century innovation reality.

A. Growth in the Number of Examiners

One of the USPTO's primary responses to the increasing size and complexity of the innovation system has been to increase the number of examiners it employs. Examiners perform the most central task in the patent examination process. By assessing patent applications and determining whether they meet the threshold criteria for patentability, examiners help ensure that patents are granted when appropriate and not granted when it would be inappropriate to do so. However, examiners are under a heavy workload and able to spend only about 18 hours searching for and examining the prior art relevant to any given application.[87] This has led to a sizable backlog of applications in recent years, in response to which the USPTO has increased the number of examiners.[88]

85. *See* Minoo Philipp, *Patent Filing and Searching: Is Deflation in Quality the Inevitable Consequence of Hyperinflation in Quantity?*, 28 WORLD PAT. INFO. 117, 118 (2006).

86. *See generally* Wuchty, *supra* note 40.

87. Mark A. Lemley, *Rational Ignorance at the Patent Office*, 95 NW. U. L. REV. 1495, 1496 (2001).

88. Dennis Crouch, *USPTO's Swelling Examiner Rolls*, PATENTLY-O (Nov. 30, 2014), http://patentlyo.com/patent/2014/11/usptos-swelling-examiner.html.

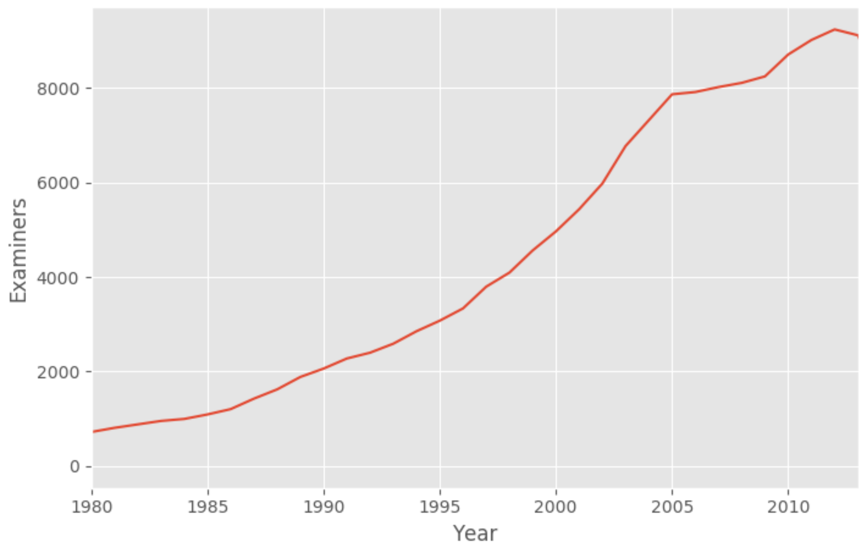

FIGURE 7: The number of unique examiner ID numbers included in the Patent Application Information Retrieval (PAIR) data.[89]

This quickly increasing number of examiners is a response to the commensurate increase in the number of patent applications submitted to the USPTO. It has allowed the Patent Office to process more applications and begin to decrease the size of the application backlog. Although this increase can help in coping with a quantitative change in patenting behavior, increasing the number of examiners does little to address qualitative changes in the way that innovation occurs.

B. Examiner Specialization

Much of the above discussion about changes in the Patent Office organization, suggested that examiners have become increasingly specialized over time. While this was almost certainly true early in the Patent Office's history, as it grew its corps of examiners from one generalist to hundreds of examiners organized into areas of specialization, it is less clear that this trend towards increased specialization has continued in recent decades. Research provides little empirical insight into the degree to which

89. Stuart J.H. Graham et al., *The USPTO Patent Examination Research Dataset: A Window on the Process of Patent Examination*, SSRN Scholarly Paper ID 2702637 (Social Science Research Network Nov. 30, 2015).

an examiner today may be more or less specialized than an examiner working at the Patent Office in the 1980s.

To provide insight into whether or not examiners are becoming more specialized, I draw on the USPTO Public Patent Application Information Retrieval (PAIR) data.[90] These data provide a record of the examination process, including unique examiner identifiers and USPC classifications for each application. Using this, I calculate the average breadth of an examiner's work over time. By breadth, I refer to the number of USPC subclasses that each individual examines at least one application within. Calculating this for every active examiner on a yearly basis, shows us how many subclasses the average patent examiner worked within each year (see Figure 9).

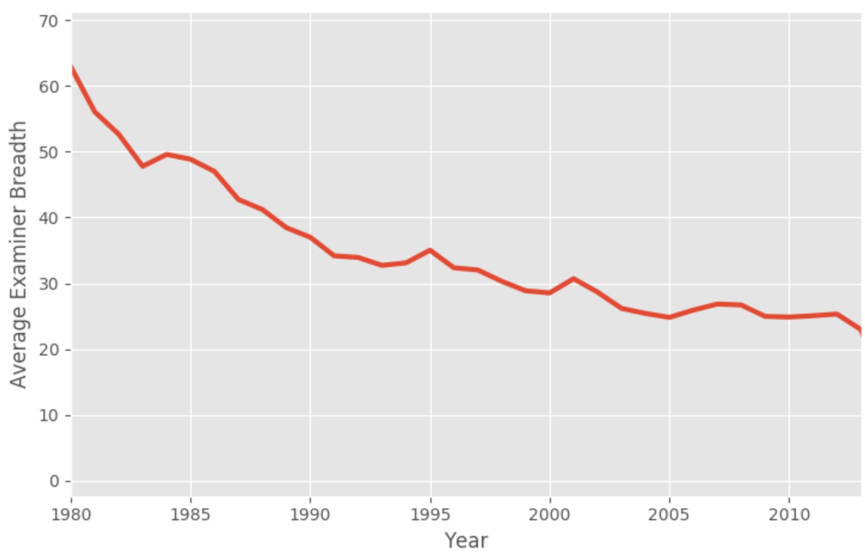

FIGURE 8: The average number of subclasses examined by a patent examiner over the course of a year's work. This includes data on 15,333 unique patent examiners' work on 7,842,980 applications.

We see in Figure 9 that in recent decades there has been a steady decrease in the number of patent classes that each examiner works within. This suggests that examiners are becoming more narrowly-focused on a specific area of technical expertise. The trend towards increasing specialization at the Patent Office is not limited to its 19th century history.

90. *Id.*

This trend has continued in the latter decades of the 20th century, and into the 21st century. What does this increasing specialization mean for the state of patent examination, when more-and-more innovation is drawing on multiple and diverse areas of expertise?

C. Innovation System Complexity & the Examination System

The above demonstrates a number of ways that the innovation system has become more complex in recent decades. Not only are more and more patents applied for, and more and more claims made, inventions now implicate more prior art, more distant prior art, and more diverse prior art. Meanwhile, the complexity of modern innovation now more often than not requires teamwork in order to generate a patentable invention. The Patent Office has responded to these developments largely by doubling-down on the existing examination model. In hopes of catching up to the flood of applications and reducing the application backlog, the Patent Office has hired more examiners, and these examiners have become increasingly specialized. While hiring more examiners has been a valid response to some of the changes we have observed within the innovation system, it is insufficient on its own to address many of the challenges the Patent Office currently faces. It represents a quantitative response to a qualitative change in circumstances.

The concern is that inadequate responses by the Patent Office and legislators to changes in the way innovation occurs will lead to an increase in the granting of "bad patents." Bad patents have a number of negative effects on the innovation system, including increasing the risk of patent thickets and increasing IP transaction costs,[91] upsetting efficient innovation incentives, and raising the risk that IP will not be put to its maximally efficient use.

In recent years there have been some initiatives and legislation aimed at solving the challenges posed by the increasing complexity of the innovation system and the associated universe of information. The "Peer to Patent" project was a pilot project aimed at increasing collaborative patent application examination, and especially relevant prior art identification.[92] It provides for an online portal where members of the public can act as examiners, discuss applications, and identify relevant prior art for selected patent applications. While this project remains in pilot stages, and at

91. *See* Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting*, 1 INNOVATION POL'Y & ECON. 119, 126 (Adam B Jaffe et al. eds., MIT press 2001).

92. *See* Naomi Allen et al., *Peer to Patent: First Pilot Final Results*, 4 (The Ctr. for Pat. Innovations at New York Law School 2012).

comparatively small scale, it does represent some action by the Patent Office towards addressing the increasing complexity of the information space.

Meanwhile, legislative changes have also attempted to respond to the challenges the Patent Office faces in locating relevant prior art. The Leahy–Smith American Invents Act of 2011 allows for third parties to submit prior art they feel is relevant to the patentability of a patent.[93] Those submissions will be entered into the patent's file and subsequently available should it be re-examined or challenged. Relatedly, the *inter partes* review process allows for third party challenges to granted patents. This allows for some policing of bad patents, so that if the Patent Office grants a patent that should not have been granted, there is some chance that an interested third party may raise a challenge and have the patent deemed invalid.

In many ways, the challenges that face the Patent Office now are similar to those that led to its inception. In the early Republic, following the Patent Act of 1793, there was no examination of patent applications. Rather, patents were granted on a registration basis. This resulted in over 10,000 patent grants, "the majority of which were either for useless inventions or used to fraudulently impose on the public."[94] This proliferation of bad patents led to the creation of the Patent Office in 1830, and a wholesale restructuring of the American patent system. The current challenges facing the patent system may not demand such wide-ranging changes, but the 20th century model currently employed by the Patent Office needs some changes to help it adapt to the 21st century reality.

V. 21ST CENTURY ASSESSMENT FOR 21ST CENTURY INNOVATION

Perhaps the greatest challenge the Patent Office faces in responding to changes in the innovation system is the fact that these changes have been both quantitative and qualitative in nature. Responding to a solely quantitative change is generally a simple proposition. In the context of patent examination, providing more examination resources by way of hiring an increased number of examiners and/or allowing more time for them to perform their examinations. On the other hand, responding to a qualitative change requires much greater transformation, involving not just an increase in resources but also more fundamental alterations to the patent examination process.

93. 35 U.S.C. § 1 (2011).

94. Edward C. Walterscheid, *Patents and Manufacturing in the Early Republic*, 80 J. PAT. & TRADEMARK OFF. SOC'Y 855, 886 (1988).

The changes that the Patent Office has made in recent years as they have hired more examiners, and altered the way their time is accounted for are insufficient responses to the transformation we have seen in the nature of innovation. Although the peer to patent pilot project, and changes contained within the America Invents Act represent steps in the right direction, without more thorough changes to the examination system, we risk examiners allowing more-and-more low quality patents and ultimately undermining the innovation incentive system. In order to adequately respond to qualitative changes in the way innovation occurs, the Patent Office needs to consider qualitative transformations of the examination process.

A. Time for Examination

One way the Patent Office could attempt to respond to increasing patent complexity is by allowing examiners more time to perform each examination. There have been some relatively minor changes in this area in recent years, but it is unclear how effective these changes been in actually enabling more thorough application examination. For most of recent Patent Office history, the system for allocating time to patent examinations remained unchanged.[95] The count system, enacted in 1976 and in effect until 2009, stipulated the number of hours patent examiners are expected to take for each application. The number of hours varies based on the examiner's seniority and the type of technology claimed in the application, moving up or down from the 20.1 default hours per application.

The changes enacted in 2009 aimed to give examiners "more time overall, more time for a first action on the merits, and time for examiner-initiated interviews."[96] Research suggests that examiners with less time to spend on their examinations grant more bad patents.[97] However, the recent increase in time was relatively minimal amounting more to a change in the manner that the Patent Office counted various types of office actions rather than a significant increase in the resources available to examine any given patent application.

95. U.S. PAT. & TRADEMARK OFF., RECENTLY ANNOUNCED CHANGES TO USPTO'S EXAMINER COUNT SYSTEM GO INTO EFFECT (Feb. 18, 2010), https://www.uspto.gov/about-us/news-updates/recently-announced-changes-usptos-examiner-count-system-go-effect (last accessed on Nov. 4, 2017).

96. U.S. PAT. & TRADEMARK OFF., USPTO JOINT LABOR-MANAGEMENT TASK FORCE PROPOSES SIGNIFICANT CHANGES TO EXAMINER COUNT SYSTEM (Sept. 30, 2009), https://www.uspto.gov/about-us/news-updates/uspto-joint-labor-management-task-force-proposes-significant-changes-examine-0 (last accessed on Nov. 4, 2017).

97. *See generally* Michael Frakes & Melissa F. Wasserman, *Does the U.S. Patent & Trademark Office Grant Too Many Bad Patents?: Evidence from a Quasi-Experiment*, 67 STAN. L. REV. 613 (2015).

To respond to increasing innovation complexity the Patent Office might consider increasing the flexibility in hours counted for each application assessment. Ideally, one would want the number of hours to increase for more complex technologies, and decrease when relatively simple inventions are claimed. Indeed, the current system attempts to achieve this by defining the number of hours counted per application as a function of the technology class and subclass that the application is classified within. However, using categories as a proxy for complexity provides only a rough approximation of how complex an actual invention is. This is evidenced by the fact that more-and-more inventions receive multiple categorizations, as the Patent Office's classification scheme struggles to keep up with increasing interdisciplinarity.[98] The current system has little flexibility to cope with intra-class heterogeneity of invention complexity. This leaves examiners struggling to cope with widely different types of patent applications within the same time allotment.

For example, compare two patent applications in class 725: application numbers 10,100,643 and 10,434,042. The first of these (the '643 application) claimed a "Multimedia display system using display unit of portable computer, and signal receiver for television, radio, and wireless telephone." The second (the '042 application) claimed a "Method and apparatus for browsing using multiple coordinated device sets." Because both of these applications were in technology class 725 (interactive video distribution systems) they would each have an expectancy of 31.6 hours.[99] However, they are starkly different in their levels of complexity and the amount of work they would have required to process. For instance, the '643 application had a description that was 3,443 words long and included 2 independent claims and 3 dependent claims. The specification for this application ran 10 double-spaced pages. Meanwhile, the '042 application's description ran 110,483 words long and included 37 independent claims and 247 dependent claims. This longer application's specification was 247 pages long as submitted.

There are a number of ways that the Patent Office could alter their current count system to be more responsive to within-category differences in technological complexity. Perhaps the easiest to institute, would be a system that combined the current categorization task with a complexity assessment. Currently, when new applications are submitted to the Patent Office, they are categorized according to the technology subclasses they fit within. During this procedure, the officer charged with categorization could also

98. *See* Youn, *supra* note 49, at 3.

99. This is the base expectancy for class 725. The actual expectancy is calculated by dividing the expectancy by the position factor, which is a function of a patent examiner's rank.

assess and grade the complexity level of the invention. Those inventions with higher complexity grades would be allotted more count credit, allowing examiners more time to assess their applications. This solution is challenging for a number of reasons. One, it requires the individual charged with categorizing the applications to have sufficient expertise to assess complexity. As we've seen above, there are an ever-increasing number of technological areas that inventions may occur in. Any given individual can only be conversant in a small number of these areas. Thus, the complexity assessment task might be best handled by individual topic-area experts. This however, raises many of the challenges noted above regarding the increasing commonality of cross/multi-disciplinary work.

Another potential way to classify applications based on the underlying complexity of the invention claimed would be to develop algorithmic ways of doing so. This method would require substantial engineering and testing, but machine learning techniques may assist in more accurately assigning count values to applications than the current relatively naïve technology classification based system. This approach would likely work best with a semi-supervised learning solution that would use expert-coded complexity assessments to train a model that would automatically assess the complexity of new applications and assign the count value based on that assessment. The downside of a machine learning approach is that it may appear somewhat opaque in application. The current system has clear rules, and examiners know and understand why they are allotted the hours they are for current applications. If on the other hand a computer-derived model were in charge of allotting examination hours, examiners may not appreciate the move from a clear rule-based system to one that is perhaps more difficult to understand and explain.

The increasing trend towards multiple classifications for application[100] could provide another way to add nuance to the current complexity assessment model. These classification combinations could be assessed on an "atypicality" scale,[101] giving more time to those inventions that are classified in combinations of subclasses that are rarely combined. One of the benefits of this sort of solution is that it requires relatively little change from the current system. Applications are already classified early in the examination process. Adding a step that then determines how likely that particular combination of classifications is would be relatively straight forward to implement. One of the downsides of this solution is that it relies on metadata about the underlying invention, which is by definition somewhat

100. *See* Youn, *supra* note 49, at 11.
101. *See generally* Uzzi, *supra* note 59.

coarse and lacking in detail. However, the current system shares this flaw, and adding this sort of combinatorial approach to complexity analysis would almost certainly be an improvement over the current model.

Yet another way to provide more nuanced application complexity assessment would be to allow examiners more freedom to identify particularly complex inventions and be granted additional time to engage in their prior art search. The current count system does not compensate examiners for hours they spend examining an application beyond those allotted by the model. Allowing examiners a number of complex invention count extensions per year could help ensure that particularly complex inventions are not subjected to insufficient scrutiny due to their complexity. The challenge here is in setting efficient examiner incentives and ensuring that the extension system is not abused.

B. Team Assessment

The Patent Office is not the only institution that has been forced to cope with assessing the quality of increasingly complex knowledge. The world of science has long faced similar challenges, as scientists engage in highly-specialized work and then submit their results for consumption by the general community. In order to ensure that weak science is not unduly circulated, scientists have evolved the norm of privileging work that has undergone thorough peer review.

In some ways, the peer review model has many similarities with the current patent examination process. Examiners review the application's claims, and in doing so use their expertise and the extensive information resources available to them to assess whether they meet the legal requirements for patentability. Similarly, peer reviewers review a manuscript and use their expertise to assess its contribution to the state of knowledge and suggest ways the work could be improved. The greatest two distinctions between the peer review process and the patent examination process are the fact that peer review almost always uses multiple independent experts to assess quality, and peer review incorporates more dialogue between reviewers and scientists, with reviewers often taking an active role in attempting to improve the quality of the research under review.

The Patent Office could learn from the first of these distinctions, with multiple independent reviewers assessing the merits of any piece of research. This would help improve the quality of assessment as multiple perspectives are more likely to lead to an optimal outcome by correctly distinguishing between patentable and unpatentable inventions. The benefits accruing from greater expertise and broader familiarity with the knowledge space are perhaps the greatest advantages that using multiple examiners would bring to the examination process. More examiners assessing an application would mean that they are collectively more likely to be familiar with, or to identify prior art that calls into question the patentability of the underlying invention. As coping with the ever-growing burden of knowledge is one of the chief challenges facing the present-day patent assessment system, the information awareness and processing advantage offered by multiple examiners offers great potential improvement for the examination system.

The most obvious challenge of instituting a multiple-examiner system would be the increased costs and drain on Patent Office resources. The USPTO is already straining under the load of an increasing number of patent applications.[102] Having multiple examiners assess applications would add a great deal more strain on Office resources. This challenge could be addressed by reserving the multiple examiner approach for high complexity inventions. In a method analogous to that discussed above regarding adding more nuance to the examination count system, the Patent Office could classify some applications as "high complexity" and require that those applications be subjected to multiple reviews before a patent will be granted.

C. Crowd Sourcing Prior Art Identification & Patent Challenges

Using a crowd sourcing model to assist in patent application examination would go a step beyond instituting team assessment. The difficulty in identifying relevant prior art is perhaps the greatest challenge that Patent Offices face in the 21st century. As demonstrated above, the universe of available information has grown exponentially, making it more-and-more difficult to determine whether a claimed invention truly is novel and nonobvious. There are a number of ways to cope with this growth in the amount of potentially relevant information. One response is to provide more structured prior art databases, effectively decreasing examiner search costs, and thereby increasing their likelihood of identifying relevant prior art. Evidence suggests that doing so will lead examiners to be more stringent in their application assessments.[103] This information-structuring response shows promise and should certainly be pursued. However, it is costly to perform and will almost certainly never enable examiners to always identify all relevant prior art.

102. *See* Jason D. Grier, *Chasing Its Own Tail - An Analysis of the USPTO's Efforts to Reduce the Patent Backlog*, 31 HOUS. J. INT'L L. 617, 626 (2009).

103. Prithwiraj Choudhury & Tarun Khanna, *Ex-Ante Information Provision and Innovation: Natural Experiment of Herbal Patent Prior Art Adoption at the USPTO and EPO*, 618–651 (Harvard Business School - Working Papers 2015).

Another approach is to have more individuals engage in the search. Opening up the prior art search and identification process in this manner is grounded in a belief that there are types of problems that benefit from having many—potentially anonymous to one another—unique individuals attempting to solve. In the field of open source software, this belief is often characterized as Linus's law—named after Linus Torvalds, the original Linux developer—stating that "given enough eyeballs, all bugs are shallow."[104] In a similar manner, with sufficiently numerous, diverse, and capable searchers any prior art search will identify the entire universe of relevant prior art, as all searches will become shallow.

This multiple simultaneous searcher philosophy underlies the peer-to-patent pilot project discussed above. However, that project has been limited in scope thus far and it is uncertain how well it will scale. It is quite possible that much of the activity in the peer to patent reviews that have occurred under the pilot project were driven largely by the novelty of the project and may not scale well under a long-term implementation of a similar system. Perhaps the greatest challenge is in providing sufficient motivation for individuals to contribute to the search process. Patent examiners are paid well to examine applications, but individual citizens do not have the same incentive to spend their time identifying relevant prior art.

In recent years, legislation has moved the Patent Office to open up the prior art identification process. The *inter partes* review (IPR) system—created with the enactment of the Leahy–Smith America Invents Act on September 16, 2012—includes a mechanism by which third parties can request that the Patent Office engage in a "proceeding to review the patentability of one or more claims in a patent."[105] These proceedings begin when a third party files a petition either nine months after the patent is granted, or after the termination of a post grant review. IPR reviews are limited to patents granted under the America Invents Act first-to-file regime, and are only instituted on the basis of patent or printed material prior art and only when it seems reasonably likely that the petitioner will prevail in demonstrating the unpatentability of at least one of the claims they challenge.

The weakness of the current IPR system is that there is little incentive for parties without a personal or organizational interest in the related intellectual property to request further review. Searching for relevant

104. Eric S. Raymond, *The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*, http://www.jus.uio.no/sisu (last visited Sept. 24, 2017).

105. U.S. PAT. & TRADEMARK OFF., INTER PARTES REVIEW (2014), http://www.uspto.gov/patents-application-process/appealing-patent-decisions/trials/inter-partes-review (last accessed Sept. 12, 2017).

knowledge is a costly endeavor. Furthermore, submitting an IPR request requires the petitioner to pay significant fees ranging into tens of thousands of dollars.[106] It is unlikely that anyone without preexisting familiarity with the technological area, and an interest in blocking the grant of the patent in question would request IPR as currently designed. This weakness could be addressed by providing incentives for otherwise uninterested parties to engage in prior art search. A prize system, similar to that used by many software companies to identify bugs with their code could offer such an incentive system. If designed appropriately, a prize system need not even raise funding challenges, as the prizes could be funded by applicants themselves. Currently, patent holders must pay regular maintenance fees to maintain their patent validity.[107] These fees are in place to help discourage the under-utilization of intellectual property. If a patent is not valuable enough to the owner to encourage him or her to pay the relatively modest fees, the belief is that releasing that IP to the public domain would provide greater social utility. As currently designed, maintenance fees in the United States are due approximately at years 4, 8, and 12 after issuance, in amounts varying based on date and entity type.

In order to provide greater incentive for otherwise uninterested third parties to participate in the IPR process, instead of the current post-grant payment system, the fees could be prepaid in full and held by the Patent Office in a patent-specific account. Every year, a portion of the account holdings would be deducted to cover that year's maintenance fees.[108] If at any time an individual locates relevant prior art and uses it to request IPR that results in nullifying the patent, that individual would be entitled to the funds remaining in the maintenance fee account. This would ensure that the new inventions provide the greatest incentive for third-party prior art search. The IPR incentive would decrease over time as maintenance fees are paid and the patent stands the test of time. If at any time the patent holder wishes to abandon his or her patent, they would be entitled to the fees remaining in the maintenance fee account.[109]

One potential repercussion of an incentivized IPR system, would be an increased drain on Patent Office resources. To avoid this, the challenge

106. The base fee is $9000 to submit an IPR request. This fee can increase depending on the status of the challenged patent, whether it is a business method patent, and how many claims are challenged. 37 C.F.R. § 42.15 (2015).

107. *See* 37 C.F.R. § 1.20(e)(f)(g) (2013).

108. This would represent a change from the current once-every-four-years model to an annual maintenance fee model like that used in many other countries.

109. To avoid owners of bad patents from abandoning in the face of a potentially successful IPR challenge, recovery of maintenance fee accounts would be limited if IPR had been requested until the completion of the IPR proceeding.

system could be designed to include some cost to raise challenges to help weed out weak or frivolous challenges. The current system's fees would be too high to be sustainable, as they would cancel out any incentive that potential challengers had to raise an IPR challenge. To be sustainable, the fees would have to be significantly lower than the potential payout. These fees would both help avoid frivolous review requests while at the same time help to offset the drain on Patent Office resources by offering another potential fee revenue stream.

D. Analogous Art

There is a considerable amount of patent law doctrine that currently dictates how far through the knowledge space we expect information to travel. This "analogous art" doctrine demonstrates the belief that new applications of pre-existing ideas are desirable only if the application is within a context that is far enough removed from prior applications so as to constitute a nonobvious improvement on the state of the art.[110]

One of the implications of the above empirical demonstration of the increasing complexity and inter-connectedness of the information space is that the distance between analogous arts has effectively been steadily decreasing in recent decades. If this is the case, the definition of what constitutes analogous art should be becoming more inclusive as this distance decreases. This is because the analogous art doctrine exists largely to avoid granting novel, but obvious re-purposing of existing inventions. The belief is that if an invention is applied in an analogous area, it is not deserving of patent protection, largely due to obviousness reasons—we believe that if it is useful the application to analogous fields will happen even without the incentive provided by patent protection. On the other hand, once the application of an invention or idea moves to a sufficiently distant research area, it remains optimal to maintain the incentive of patent protection in order to encourage inventors to go through the work of translating the distant field's knowledge to their own domain.

With the increasing connections between diverse technical and scientific areas, and decreased information search costs, we have seen an increased tendency for inventors to incorporate ideas from outside their own immediate technical areas. In much the way that globalization has made the world effectively smaller, so too have transformations in research processes and information technology capabilities made the information space smaller. The result is that prior art that was once distant and of a distinct discipline,

110. *In re* Bigio, 381 F.3d 1320, 1325 (Fed. Cir. 2004).

has become analogous. The challenge, as with so many issues within intellectual property law doctrine, is in optimally determining where the line between analogous and non-analogous art lies.

Currently, a prior art reference is considered analogous if it is either (1) in the same field of endeavor as the invention or (2) "reasonably pertinent" to the problem the inventor is attempting to solve.[111] The second prong of this test is the most ambiguous, providing little certainty as to what constitutes analogous prior art and what does not. Its flexibility is both this rule's primary strength and its primary weakness. There is no bright line rule for what patent examiners or inventors should consider analogous and what they should consider non-analogous art. Current analogous art doctrine requires examiners to look for some evidence of "nonanalogy" or "analogy" between the claimed invention and the prior art (MPEP § 2141.01(a)). This is obviously a subjective standard that leaves much to the interpretation of the patent examiner assigned to assess any given application.

Expanding the universe of what prior art is considered "analogous" could help re-balance the innovation incentive system in response to the changes observed above. We saw above that inventors have become more-and-more likely to draw on distant prior art and integrate it into their inventions. Regardless of why this is the case—whether it be due to improved search capabilities, an increase in teamwork, or other reasons—the effect is that knowledge now diffuses further through the knowledge space than it did only a few decades ago. While this is likely a good thing, it does pose challenges for the intellectual property system. If it has grown easier to integrate distant knowledge, the incentives provided by intellectual property law should be altered to ensure that inventions that would have been timely created without the incentive provided by patent law are not granted patent protection. One way to shift the analogous art definition would be to presume that *all* prior art is analogous, unless the inventor can provide some convincing argument that it is not. Shifting the burden in this manner could help reduce the number of bad patents granted, while also making post-grant review more effective.

Another potential reform that could improve the current analogous art doctrine would be to use algorithmic methods to more clearly identify analogous prior art. The methods used above to measure similarity between inventions and other similar information comparison techniques could be sued to help provide insight into where exactly that line lies. While a vector space based invention comparison is likely too inexact to provide a definitive

111. *In re* Klein, 647 F.3d 1343, 1348 (Fed. Cir. 2011).

determination as to what is, or is not, analogous, they could certainly provide quantifiable insight as to where that line has been drawn in the past, and guidance as to the bounds within which it might be drawn now. Similarly, machine learning models could be trained to help distinguish between analogous and non-analogous prior art.

The empirical evidence presented in Section III clearly demonstrates changes in the way innovation occurs in the 21st century. These changes have important implications for the way examiners categorize prior art as analogous or non-analogous. As inventors have become more likely to translate and integrate distant knowledge, the scope of what should be considered "analogous" has changed. Whether it be by changing the examination procedure to include a presumption of analogousness, or by moving towards algorithmic identification of analogous prior art, or by some other policy change, the Patent Office needs to respond to these changes in the way information is recombined if it wishes to remain abreast of the way that 21st century innovation occurs.

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The above discusses a variety of reforms that could be instituted by the Patent Office and Congress in order to help the USPTO respond to changes in the innovation system. Whether it be by altering the way time is allotted to examiners for their examinations, by including some framework for increased teamwork during the examination process, by providing greater incentive for third parties to identify relevant prior art and challenge patents, or by expanding the scope of what is considered analogous prior art, there are a variety of ways policy changes that would help the patent examination adapt in response to changes in the innovation environment.

VI. CONCLUSION

This article has focused on exploring the implications of changes in the innovation process on the way we assess and incentivize innovation. Since the inception of intellectual property law systems, the way we assess innovation has consistently responded to the nature of the innovation process. At one point, when innovations did not flow easily across national borders, England provided patents not only to inventors but also to those who were the first to import and apply a technology or process. In the early history of the American Patent Office, examiners were general experts, there was no system to categorize patents, and every publication was considered analogous prior art. As innovation and the information environment evolved, so too did the Patent Office. It hired more examiners, those examiners specialized, and the Office began to categorize patents to improve search capabilities.

Many of these changes to the Patent Office and examination process took place in the 19th and 20th centuries as the Office responded to the huge growth in the number of new inventions claimed, and the amount of information examiners had to cope with. These were essentially quantitative changes, that the Office responded to by increasing its size and improving its information organization. However, towards the end of the 20th century and as the 21st century began we saw not just continued quantitative growth in the amount of innovation occurring and information production, but also qualitative changes in the way innovation occurred. Inventors were not just claiming more inventions, they were claiming different sorts of inventions. As inventors have tended to reach further across the knowledge space, and translate and integrate more distant knowledge, inventions have become more complex requiring an understanding of more diverse scientific and technical areas.

These changes pose significant challenges to the traditional solitary examiner model. As inventions become more complex and interdisciplinary, the ability of individual experts to adequately assess their patentability becomes increasingly strained. The 20th century patent assessment model is becoming increasingly out of step with the 21st century innovation reality. The Patent Office needs to continue to evolve if it hopes to adequately respond to the challenges posed by changing innovation norms, and a growing and increasingly complex information environment.