ARE PATENTS CREATIVE OR DESTRUCTIVE?

TOM NICHOLAS*

Patent aggregation is not a new phenomenon—the practice of acquiring patents in order to profit from their sale or from licensing fees has a long history going back to the middle of the 19th century when trade in invention in the United States first began.[1] But recent high profile instances in which intellectual property (IP) has been acquired, in particular by non-practicing entities such as the patent aggregator Intellectual Ventures (which holds a worldwide portfolio of approximately 30,000–60,000 patents),[2] has led to renewed debate about the most appropriate incentives for promoting innovation.

Patent law is based on the idea that a temporary monopoly is a necessary reward for innovative effort and that short run deadweight loss is tolerable in return for incentives to invent. Patent aggregators may curb incentives to invent by rent seeking from creative inventors.[3] According to this view, patent aggregators distort the patent system and undermine the IP marketplace. While legitimate patent transactions and disputes over IP should be encouraged, Robert Merges has argued, for example, that "the legal system must shut down markets when the things being exchanged have no social value."[4]

Yet, while patent aggregators have been criticized for exploiting genuine inventors, a more favorable interpretation of their activities is that they are intermediaries bridging the gap between inventors and firms in the market for

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* William J. Abernathy Professor of Business Administration, Harvard Business School. I thank the Division of Research and Faculty Development for funding. I thank Tom Brown and Greg Leonard for very helpful comments and suggestions.

[1] Naomi R. Lamoreaux, Kenneth L. Sokoloff & Dhanoos Sutthiphisal, *Patent Alchemy: The Market for Technology in U.S. History*, 87 BUS. HIST. REV. 3, 5 (2013).

[2] Tom Ewing & Robin Feldman, *The Giants Among Us*, 2012 STAN. TECH. L. REV. 1, 5, stlr.stanford.edu/pdf/feldman-giants-among-us.pdf.

[3] It seems reasonable to assume that the largest negative effect would be on incentives to invent at the product development stage of the R&D process, but because of feedback loops between product development and upstream fundamental research it is also possible that patent litigation in this area curbs incentives more generally.

[4] Robert P. Merges, *The Trouble with Trolls: Innovation, Rent-Seeking, and Patent Law Reform*, 24 BERKELEY TECH. L.J. 1583, 1583 (2009), www.btlj.org/data/articles/24_4/1583_Merges.pdf.

innovation.[5] A vibrant market for ideas leads to expectations of payoffs. These payoffs, in turn, provide incentives for new research and development, which promotes technological advance. The upshot of the debate is that arguments can be constructed that go both ways. Patent aggregators either undermine the very foundations of IP or they are a necessary prerequisite for innovation markets to develop and efficiently function.

Firms like Intellectual Ventures justify acquiring and enforcing large portfolios of patents on the basis of the argument that patents encourage technological development. But this assertion itself has been contentious in research on the economics of innovation for decades. In 1951 Edith Penrose famously conjectured that "[i]f national patent laws did not exist, it would be difficult to make a conclusive case for introducing them; but the fact that they do exist shifts the burden of proof and it is equally difficult to make a really conclusive case for abolishing them."[6] More than half a century later the debate is ongoing. Michele Boldrin and David Levine put forward the case for abandoning the patent system altogether.[7] Robert Merges, on the other hand, staunchly defends the very fundamentals of IP.[8] Adam Jaffe and Josh Lerner, while noting the importance of IP, highlight the defects of the U.S. patent system, such as the granting of frivolous patents and the unnecessary proliferation of patent litigation.[9]

Whether patents are a creative or a destructive influence on innovation is fundamentally important in light of the fact that most countries currently have patent laws and the significance attached to IP rights in policy discussions. If the patent aggregators are right that patents promote technological discovery, then basic statistics on patents suggest innovation is flourishing. Notably, around one million patents are granted each year globally.[10] In the United States alone more than eight million patents have been granted since the 1836 Patent Act set the foundation for modern patent law.[11] More recently, the Patent Law of the People's Republic of China went into force in 1984 and patenting has proliferated ever since. In 2011 China surpassed the total number of

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[5] *See* ASHISH ARORA, ANDREA FOSFURI & ALFONSO GAMBARDELLA, MARKETS FOR TECHNOLOGY: THE ECONOMICS OF INNOVATION AND CORPORATE STRATEGY 8 (2001).

[6] EDITH T. PENROSE, THE ECONOMICS OF THE INTERNATIONAL PATENT SYSTEM 40 (1951).

[7] MICHELE BOLDRIN & DAVID K. LEVINE, AGAINST INTELLECTUAL MONOPOLY (2008).

[8] ROBERT P. MERGES, JUSTIFYING INTELLECTUAL PROPERTY (2011).

[9] ADAM B. JAFFE & JOSH LERNER, INNOVATION AND ITS DISCONTENTS: HOW OUR BROKEN PATENT SYSTEM IS ENDANGERING INNOVATION AND PROGRESS, AND WHAT TO DO ABOUT IT (2006).

[10] WIPO, WIPO IP Statistics Data Center, ipstatsdb.wipo.org/ipstatv2/ipstats/patentsSearch (last visited Nov. 2012).

[11] *Table of Issue Years and Patent Numbers, for Selected Document Types Issued Since 1836*, U.S. PATENT & TRADEMARK OFFICE, www.uspto.gov/web/offices/ac/ido/oeip/taf/issuyear.htm.

patents granted in a year in the United States.[12] All the statistics indicate that patents represent a key component of the IP framework around the world.

To the extent that there is still considerable debate and disagreement about the usefulness of patents as a mechanism for spurring technological development, in this article I survey recent contributions to the literature. The main objective is to determine whether the argument frequently put forward by patent aggregators—that patents encourage innovation—has any basis. Although IP covers patents, copyright, and other mechanisms, given the sheer size of the scholarly literature, I confine most of the analysis to contributions that focus on patents.

I. PATENTS AND INCENTIVES TO INVENT

From the very beginning, patents in the United States were subject to debate about tradeoffs. Patents were first introduced in 1790 when Thomas Jefferson became the first patent commissioner and examiner. Initially, Jefferson strongly opposed the idea of extending a monopoly to an inventor on the basis that only those who could afford it would be able to benefit from the invention. His belief that new knowledge was a public good meant that he refrained from patenting his own discoveries, such as the innovative agricultural machinery he developed for working his Virginia plantation. Jefferson's opposition to patents derived from his utilitarian belief in the process of science and invention and from the freedoms advocated by the new Constitution. Later, after appreciating the virtue of patents as an incentive mechanism, Jefferson became more predisposed to the use of patent protection for inventions under the assumption that "ingenuity should receive a liberal encouragement."[13]

After revising the rules concerning the validity of patents and examination requirements, the United States adopted a system in 1836, the basic hallmarks of which can still be observed today. Under modern patent legislation patents serve two functions: first, to promote innovation by permitting inventors to appropriate returns from their research and development efforts; and second, to diffuse the knowledge that results from new discoveries by requiring the inventor to publicize the technical ideas as a patent in sufficient detail to allow a skilled person to reproduce the invention.

At one level the justification for IP is a deep-rooted philosophical one. Most prominently, Robert Merges makes a compelling argument for the existence of IP as a device to reward creativity and inventiveness. While much of Mergers' discussion focuses on IP broadly defined, the rationale for patents

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[12] WIPO, *supra* note 10.

[13] Letter to Oliver Evans (May 2, 1807), *in* 11 THE WRITINGS OF THOMAS JEFFERSON 200, 202 (Albert Ellery Bergh ed., 1905).

follows from the same intellectual foundations. Patents reward inventive effort and when subjected to appropriate limits can achieve socially efficient outcomes. The well-known writings of liberal philosophers including John Locke, Immanuel Kant, and John Rawls, offer foundational principles. Extrapolating from their views, IP is consistent with fairness and distributive justice. Society needs these foundations in order to function effectively.[14]

While philosophical justifications can be debated on the grounds of different interpretations of scholarly arguments, economic justification of IP is open to considerable debate because of conflicting empirical findings concerning the value of patents. One of the most common arguments for patents relates to the inability of markets to provide the necessary inducements for invention. Competitive markets may generate more innovation because, under monopoly, incumbents are reluctant to replace their existing stream of rents. Yet, competition is no panacea because, if sufficient returns cannot be appropriated by the inventor undertaking the original R&D expense, this leads to underinvestment in technological development.[15]

Patents provide a possible way to overcome this problem by allowing for appropriability over the term of the patent in return for promoting disclosure. However, the mechanism is imperfect because protecting investments in new knowledge through patents provides financial rewards at the cost to society of excludability. This inefficiency is only tolerable because inventors are incentivized to innovate further as a consequence of the right to profit through a patent. In other words, the economic justification for patents stems from a belief in the idea that dynamic positive effects on innovation associated with IP outweigh the static costs.

Theorists have long considered altering the length and breadth of patent protection to enhance the efficiency with which patents act as an incentive to invent. In a pioneering theoretical contribution, William Nordhaus determined the optimal patent life when there are two forces at work: monopoly payoffs to inventors, which favors longer patent lives, and deadweight losses resulting from monopoly, which favor shorter patent lives. He found that shorter patent lives were socially optimal, especially where demand is more elastic. The more demand moves in response to price the greater the static welfare loss is from allowing an inventor, or a firm, to extract supernormal returns from a patent.[16]

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[14] MERGES, *supra* note 8.

[15] Richard Nelson, *The Simple Economics of Basic Scientific Research*, 67 J. POL. ECON. 297, 302–04 (1959); Kenneth Arrow, *Economic Welfare and the Allocation of Resources for Invention*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY: ECONOMIC AND SOCIAL FACTORS 609, 619 (1962).

[16] WILLIAM NORDHAUS, INVENTION, GROWTH AND WELFARE: A THEORETICAL TREATMENT OF TECHNOLOGICAL CHANGE (1969).

Nordhaus's work opened up a large literature. F.M. Scherer argued that short patent lives, or early compulsory licensing, would make sense with extensions to the patent life being granted for truly breakthrough ideas.[17] Further contributors, such as Richard Gilbert and Carl Shapiro, concluded that narrow patents with longer length minimize welfare losses. Long patents allow inventors time to recover their R&D costs, while narrowness keeps open the possibility of positive competitive pressures from the development of substitute inventions.[18]

One problem with early theoretical approaches is that, for reasons of analytical convenience and tractability, they abstract from cumulative technological developments. This problem was addressed in work by Jerry Green and Suzanne Scotchmer on sequential innovation.[19] The literature shows that where innovation occurs in sequences and technology develops cumulatively, the question of optimal patents is a complex one. The main policy question here is how to calibrate the theory to practice. Some theoretical models suggest that patent policy should be geared so that the first innovator can appropriate, and diffusion promotes further developments.[20] Other work, however, suggest that weak patents may be preferable so that the first innovator cannot stifle second stage developments.[21]

The question of optimal patent length is an important one in theory, but it is complicated in practice given the variability of what may be described as *effective* patent lives, or the length of market exclusivity. According to Edwin Mansfield, in some industries approximately 60 percent of patents are effectively terminated within four years due to natural obsolescence of the technology.[22] In more recent work, Eric Budish, Benjamin Roin, and Heidi Williams show that the time lag between invention (when the patent application occurs) and commercialization (when the patent holder starts to capture supernormal returns) varies significantly across industries. Consequently, inventions with longer gestation periods may have relatively lower levels of R&D investment compared to inventions with shorter gestations because longer gestation is

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[17] F.M. Scherer, *Nordhaus' Theory of Optimal Patent Life: A Geometric Reinterpretation*, 62 AM. ECON. REV. 422 (1972).

[18] Richard Gilbert & Carl Shapiro, *Optimal Patent Length and Breadth*, 21 RAND J. ECON. 106 (1990).

[19] Jerry R. Green & Suzanne Scotchmer, *On the Division of Profit in Sequential Innovation*, 26 RAND J. ECON. 20 (1995).

[20] Howard F. Chang, *Patent Scope, Antitrust Policy, and Cumulative Innovation*, 26 RAND J. ECON. 34 (1995).

[21] Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839 (1990).

[22] Edwin Mansfield, *R&D and Innovation: Some Empirical Findings*, *in* R&D, PATENTS AND PRODUCTIVITY 127, 143 (Zvi Griliches ed., 1984).

equivalent to a shorter "effective" patent term.[23] The context these authors are analyzing is important. Cumulative innovation is a characteristic of many industries as inventors "stand on the shoulders of giants," but the nature of cumulativeness depends on industry settings. Some industries like semiconductors are highly cumulative based on the use of prior knowledge for improvement, whereas others like consumer products are less so.

Despite the importance of cumulative innovation to patent policy, empirical evidence on the link between cumulativeness and IP protection is limited. An important contribution to this area is Heidi Williams's study of the recent race to understand the structure, organization, and function of human genes. Williams analyzes differences in innovation outcomes between the Human Genome Project (HGP), whose genes were in the public domain, and genes mapped by a private company, Celera, that were protected by IP between 2001 and 2003. Celera won the race and had IP protection for about two years before HGP successfully re-sequenced. Williams's analysis shows Celera's IP significantly depressed follow-on innovations relative to the hypothetical case where Celera genes had been freely available.[24]

At a practical level, Dan Burk and Mark Lemley offer guidance for the relationship between patents and incentives to invent, specifically arguing for different policy levers in different industries. Their main motivation is that factors, such as the cost of technological development and the degree of cumulativeness, are quite different in, for instance, biotechnology and information technology yet both industries are subjected to the same patent laws. A solution would be to take more explicit account of industry-specific factors when interpreting patent legislation and formalize these new interpretations as opposed to adopting ad hoc implementations. For example, changing obviousness requirements in line with the rapidly changing environment in the biotech industry could improve the quality of patents. In information technology areas like semiconductors, narrower patents could be appropriate given the cumulative characteristics of technological development.[25]

Industry-specific contingencies appear to be appropriate given that the propensity to patent varies strongly across industries. Patenting rates tend to be much higher in the chemicals industry versus the food industry, for example, given differences in the patent-secrecy tradeoff. Wesley Cohen, Richard Nelson, and John Walsh were the first to document this fact using a 1994 survey

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[23] Eric Budish, Benjamin N. Roin & Heidi Williams, *Do Fixed Patent Terms Distort Innovation? Evidence from Cancer Clinical Trials* (Nat'l Bureau of Econ. Research, Working Paper No. 19430, 2013).

[24] Heidi L. Williams, *Intellectual Property Rights and Innovation: Evidence from the Human Genome*, 121 J. POL. ECON. 1 (2013).

[25] DAN L. BURK & MARK A. LEMLEY, THE PATENT CRISIS AND HOW THE COURTS CAN SOLVE IT (2012).

administered to a large sample of U.S. R&D firms. They found strong between-industry differences in the propensity to patent and, moreover, that as a general rule, "patents tend to be the least emphasized by firms in the majority of manufacturing industries, and secrecy and lead time tend to be emphasized most heavily."[26] According to James Anton and Dennis Yao, it makes sense for firms to protect influential innovations using secrecy rather than patents. If IP rights are weak the threat of imitation is much higher, partly as a consequence of patent disclosure.[27] James Bessen and Michael Meurer estimate that approximately 15 percent of all R&D in the United States is performed by firms that hold no patents at all.[28]

Given this statistic, and the fact that secrecy may be a viable option, why do firms engage in the expense of patenting at all? One explanation is that startup firms may choose to patent to avoid expropriation of their ideas and to establish rights over the use of an invention which can then be sold in the marketplace.[29] More broadly, Klaus Kultti, Tuomas Takalo, and Juuso Toikka argue that in high-tech industries where inventors often make simultaneous independent discoveries, patenting an invention is a better solution than secrecy because the risk that a competitor will develop and patent the invention is high. If the invention is patented, society benefits from mandatory information disclosure and the diffusion of technological knowledge. Under these circumstances stronger patent protection spurs innovation.[30]

II. EVIDENCE FROM CHANGES IN PATENT LAWS

If patents do create powerful incentives to invent, we should be able to observe changes in innovation associated with changes in patent laws. Two frequently referenced studies by Juan Ginarte and Walter Park and Sunil Kanwar and Robert Evenson imply a positive effect of the strength of patent rights on innovation.[31] Although these studies are carefully done, they use cross-country regression results for inference, and therefore confounding in-

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[26] Wesley M. Cohen, Richard R. Nelson & John P. Walsh, *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)* 1 (Nat'l Bureau of Econ. Research, Working Paper No. 7552, 2000).

[27] James J. Anton & Dennis A. Yao, *Expropriation and Inventions: Appropriable Rents in the Absence of Property Rights*, 84 AM. ECON. REV. 190, 190–91 (1994).

[28] JAMES BESSEN & MICHAEL JAMES MEURER, PATENT FAILURE: HOW JUDGES, BUREAUCRATS, AND LAWYERS PUT INNOVATORS AT RISK 98 (2009).

[29] Joshua S. Gans, David H. Hsu & Scott Stern, *The Impact of Uncertain Intellectual Property Rights on the Market for Ideas: Evidence from Patent Grant Delays*, 54 MGMT. SCI. 982, 985, 996 (2008).

[30] Klaus Kultti, Tuomas Takalo & Juuso Toikka, *Secrecy Versus Patenting*, 38 RAND J. ECON. 22 (2007).

[31] Juan C. Ginarte & Walter G. Park, *Determinants of Patent Rights: A Cross-National Study*, 26 RES. POL'Y 283 (1997); Sunil Kanwar & Robert Evenson, *Does Intellectual Property Protection Spur Technological Change?*, 55 OXFORD ECON. PAPERS 235 (2003).

fluences cannot be fully ruled out. For example, the results could be sensitive to omitted variable bias given that many factors tend to be correlated with the strength of patent protection. Ideally, the effect of patent laws on innovation should be determined using cleaner empirical tests.

Unfortunately, it is rare in the history of intellectual property rights for countries to switch their patent laws "on" and "off" in a way that lends itself to experimental analysis. The closest we have to a natural experiment is the decision by the Netherlands to abandon patent laws in 1869, which took place at a time when advocates for the abolition of patents in the mid-19th century claimed that patents provided damaging monopoly privileges. Later, political pressures went in the other direction, and the Netherlands reintroduced patents in 1912.

Using data from countries participating in the Great Exhibition in London in 1851 and the Centennial International Exhibition in Philadelphia in 1876, Petra Moser examines the effect of patent laws on innovation. The data include inventions from countries that did, and did not, have patent laws, and the time period also brackets patent reform in the Netherlands. A further advantage of the dataset is that it includes *all* inventions, not just patented inventions. Hence, it can be used to analyze the patent-secrecy tradeoff at the country-industry level.[32] The findings from the analysis echo those of Cohen, Nelson, and Walsh because the vast majority of inventors at both international exhibitions did not patent.[33] More importantly, in countries without patent laws, Moser's data reveal a larger share of innovation took place in industries where inventions could be protected by secrecy. The share of inventions in food processing (an industry where secrecy dominates over patenting) increased significantly after the Netherlands abolished patents. Given the tradeoff between secrecy and patenting, the study finds that patent laws may exert more of an influence on the technical areas in which inventors choose to focus their efforts (i.e., the direction of technological change) rather than on the level of effort that they choose to invest in inventive activity.

A number of studies have made further progress on the analysis of patent laws. In my research, I have exploited the reform associated with the 1883 Patents Act in Britain which reduced patent filing fees by 84 percent.[34] I find that the propensity to patent increased significantly after the reform, but that there was no increase in the quality of inventive activity. In other words, the

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[32] Petra Moser, *How Do Patent Laws Influence Innovation? Evidence from Nineteenth-Century World's Fairs*, 95 AM. ECON. REV. 1214 (2005).

[33] Cohen et al., *supra* note 26.

[34] Tom Nicholas, *Cheaper Patents*, 40 RES. POL'Y 325 (2011).

evidence suggests that lower patenting fees meant inventors patented more, but not innovated more.[35]

Using a broader set of observations with respect to patent fees charged by the European, Japanese, and U.S. patent offices since 1980, Gaetan de Rassenfosse and Bruno van Pottelsberghe find a short-term elasticity of patent filings with respect to fees of between -0.06 and -0.12 and a long-term elasticity of approximately -0.30.[36] These estimates imply that a 10 percent increase in fees would lead to a 1 to 3 percent reduction in patent filings. The effects are sufficiently large to suggest that policy makers can use fees, among other policy levers, to affect the rate at which inventors apply for patents.[37]

In the most comprehensive study of innovation and patent laws, Josh Lerner uses 150 years of data for 60 countries. He shows, first, that economically more developed nations instituted patent systems that provided inventors with longer periods of time to actually put their inventions into practice in order to maintain patent protection; second, that democratic countries were more likely to offer patent protection per se and have patents with longer terms; and third, that a country's legal origin had a statistically significant effect even after holding economic growth and democracy constant. Specifically, the probability of patent protection was found to be higher in countries with civil-law traditions but common-law countries permitted inventors longer to "work" patented inventions within the country in which patent protection was granted. This study shows that patent systems do not function in isolation from deeper institutional and economic conditions specific to individual countries but rather are at least partly determined by them.[38]

Extending this work further, Lerner addresses the question of whether patents actually promote innovation. He concludes, subject to several caveats about research design (e.g., patents are an imperfect measure of innovation), that the effect may actually be negative. Using 177 changes in patent policy regimes for 60 countries over 150 years, he finds that patent applications by residents in countries undertaking the policy change fall.[39] Such findings are not specific to this study. According to Yi Qian's research on pharmaceutical patent legislation across the globe, stronger IP protection in early-stage developing countries may discourage domestic inventors from imitating and mov-

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[35] *Id.*

[36] Gaetan de Rassenfosse & Bruno van Pottelsberghe de la Potterie, *The Role of Fees in Patent Systems: Theory and Evidence*, 27 J. ECON. SURVEYS 696, 706 (2013).

[37] *Id.*

[38] Josh Lerner, *150 Years of Patent Protection*, 92 AM. ECON. REV. (PAPERS & PROC.) 221 (2002).

[39] Josh Lerner, *The Empirical Impact of Intellectual Property Rights on Innovation: Puzzles and Clues*, 99 AM. ECON. REV. (PAPERS & PROC.) 343 (2009).

ing closer to the technology frontier.[40] Although stronger patents tend to have a positive effect on foreign direct investment (because expropriation risk is mitigated[41]), strengthening patents beyond the optimal level may be damaging to domestic innovation.

III. PROBLEMS ASSOCIATED WITH PATENTS

Although the effect of patent laws on innovation may be negative beyond some threshold level, few authors go as far as suggesting that patent systems should be abandoned altogether. Among those that do, Michele Boldrin and David Levine are the most vocal. They maintain that patents have negative consequences because they negate competition and are generally unnecessary. Innovative industries such as software have developed largely without the use of intellectual monopoly. Furthermore, they maintain that empirical arguments in favor of patents in the scholarly literature are weak. They state that "there is no empirical evidence that [patents] serve to increase innovation and productivity, unless the latter is identified with the number of patents awarded—which, as evidence shows, has no correlation with measured productivity."[42]

But is a link between patents and productivity really absent? Several studies have identified robust and statistically significant relationships between patents and productivity. In line with the basic knowledge production function postulated by Zvi Griliches,[43] there are strong theoretical grounds for thinking that knowledge should be considered as a factor of production in addition to capital and labor. Using this framework and patents as a proxy for knowledge, Saul Lach finds an elasticity of knowledge with respect to Total Factor Productivity TFP at the industry-level in the United States between 1959 and 1983 of 0.3, which suggests that patents do correlate with productivity.[44]

In further work, Nick Bloom and John Van Reenen use data on the largest British firms from 1968 to 1996 to show that patents strongly impact productivity at the firm level. Theirs is one of a number of studies providing firm-level evidence.[45] As the literature has developed, researchers have used more

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[40] Yi Qian, *Do National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment?*, 89 REV. ECON. STAT. 436 (2007).

[41] Lee G. Branstetter, Raymond Fisman & C. Fritz Foley, *Do Stronger Intellectual Property Rights Increase International Technology Transfer?*, 121 Q.J. ECON 321, 324 (2006).

[42] Michele Boldrin & David Levine, *The Case Against Patents*, J. ECON. PERSP., Winter 2013, at 3, 3.

[43] Zvi Griliches, *Patent Statistics as Economic Indicators: A Survey*, 28 J. ECON. LIT. 1661, 1670–73 (1990).

[44] Saul Lach, *Patents and Productivity Growth at the Industry Level: A First Look*, 49 ECON. LETTERS 101, 104, 107 (1995).

[45] Nick Bloom & John Van Reenen, *Patents, Real Options and Firm Performance*, 112 ECON. J. CONFERENCE PAPERS C97 (2002).

refined proxies for knowledge accumulation, including citation-weighted patent counts or adjustments for the payment or non-payment of patent renewal fees.[46] These advances do not fully overcome measurement problems, but they do significantly increase the likelihood of measuring the link between patents and innovation accurately. Indeed, when using patents for empirical work, it is important to understand what information about knowledge production they convey. With properly specified econometric models, patent-based measures can inform our understanding of productivity.

Aside from the apparent disconnect inherent in Boldrin and Levine's assertion concerning the absence of an empirical patent-productivity link, their analysis does inform the debate on patents and innovation in a number of important ways. They marshal evidence showing that the majority of inventions are not patented.[47] There are notable examples of key unpatented inventions driving the development of entire industries, from the stream engine during the Industrial Revolution to computer software more recently.[48] As Boldrin and Levine point out, given the fact that most invention takes place outside the system, it is difficult to make the case for patents as a necessary prerequisite to stimulate innovation. Inventors may appropriate more through other mechanisms like first mover advantages than they do through patents.

A canonical example of patents stifling innovation that Boldrin and Levine cite is the early history of aviation.[49] During the late 19th century, free information exchange between practical tinkerers from across the globe led to a process of cumulative innovation. The Wright Brothers benefited immensely from open collaboration and learning, but their decision to apply for a patent in 1903 (the year they achieved controlled sustained flight at Kitty Hawk, North Carolina) shifted the industry to a proprietary basis. Their U.S. patent for a "flying-machine" granted in 1906 changed the industry significantly as American aircraft manufacturers diverted resources from science and technology to patent wars. European aeronautics, by contrast, was relatively unconstrained by patent disputes and, as a result, development advanced in a more rapid manner than in the United States.[50]

Examples such as the aviation patent dispute associated with the Wright Brothers illustrate that the societal cost of protecting intellectual monopoly can be high, especially given that a patent is typically associated with uncer-

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[46] Nicholas, *supra* note 33; Tom Nicholas, *Does Innovation Cause Stock Market Runups? Evidence from the Great Crash*, 98 AM. ECON. REV. 1370 (2008).

[47] BOLDRIN & LEVINE, *supra* note 7, at 191.

[48] *Id.* at 17.

[49] *Id.* at 11.

[50] Peter B. Meyer, *The Airplane as an Open-Source Invention*, 64 REVUE ÉCONOMIQUE 115 (2013).

tain outcomes in patent infringement lawsuits.[51] This is especially problematic given recent evidence showing that the growth in patents has been accompanied by a more than proportional increase in IP litigation and legal activity.[52] Litigation between Apple and Samsung Electronics highlights the significant time and financial costs forgone.[53] The jury in San Jose, California awarded Apple in excess of $1 billion, a significant but only small part of the aggregate litigation cost: Mark Lemley estimates the global smartphone patent war has cost in the region of $15–20 billion.[54] While the "normal" cost of patent litigation can be subsumed as the regular pursuit of business, costs can escalate in patent wars and reflect a substantial redirection of resources away from productive pursuits.

Another area in which IP may have distorting effects is patent pools, which represent cooperative agreements between two or more firms to license technology. On the positive side, the logic behind patent pools is that they avoid patent thickets of overlapping IP rights and provide a mechanism that offers advantages over each firm licensing its own innovation. If each firm licenses separately then aggregate royalty payments may be higher compared to the case in which a single pooling entity determines the licensing fee. A single entity can take account of the effect of the licensing fee on demand for all of the members' patents, whereas under separate licensing each patentee acts in its own best interests. Transactions costs of dealing with a single entity are lower for potential licensees and coordination costs are also much lower in pools relative to coordinating individual licensees. Furthermore, potential licensees have more incentives to invest in R&D if the formation of the pool reduces litigation risk. Recent antitrust policy has been favorable towards the formation of pools.[55]

The potential distorting effects of pools stem from changing behavior of members and non-members following the formation of the pool. Ryan Lampe and Petra Moser study the Sewing Machine patent pool, which was formed in 1856 to avoid damaging litigation between four rivals: I.M. Singer & Co., Wheeler, Wilson & Co., Grover & Baker, and Elias Howe. Lampe and Moser

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[51] Mark A. Lemley & Carl Shapiro, *Probabilistic Patents*, J. ECON. PERSP., Spring 2005, at 75, 80.

[52] WILLIAM M. LANDES & RICHARD A. POSNER, THE POLITICAL ECONOMY OF INTELLECTUALLY PROPERTY LAW 2–3 (2004).

[53] *See, e.g.*, Apple Inc. v. Samsung Elecs. Co. Ltd., Nos. 11-CV-01846-LHK (N.D. Cal. 2013), (case documents available at cand.uscourts.gov/lhk/applevsamsung); Howard Mintz, *Apple vs. Samsung: Jury to Return Thursday to Continue Deliberating High-Stakes Patent Case*, SAN JOSE MERCURY NEWS (Nov. 20, 2013), www.mercurynews.com/business/ci_24566355/apple-v-samsung-jury-return-thursday-continue-deliberating.

[54] Mark A. Lemley, *Software Patents and the Return of Functional Claiming*, 2013 WIS. L. REV. 905, 931–32.

[55] Josh Lerner & Jean Tirole, *Efficient Patent Pools*, 94 AM. ECON. REV. 691, 691 (2004).

show that, when measured by patenting activity, innovation declined for the members and non-members of the pool, and sewing machine stitch speed—a measure of innovation independent of patents—was roughly constant during the pool period but strongly increasing after the pool was dissolved in 1877.[56]

Extending this work, Lampe and Moser analyze patent pools during the Great Depression, when pools were seen to be especially favorable. They find that rather than being a positive influence, patent applications in technology areas affected by a pool actually declined after the creation of the pool relative to technology areas unaffected by a pool. Most of the effect they find can be explained by patent pools composed of substitute technologies, implying that in these cases a lack of competition reduced incentives for innovation.[57] Whereas pools of complementary technologies can facilitate efficient licensing (and are therefore frequently encouraged by regulators), pools of substitute technologies tend to close off markets to new entrants thereby restricting inter-technology competition. This finding is consistent with theoretical frameworks showing that substitute technology pools can be more detrimental to social welfare than complementary technology pools.[58]

In contrast to patent pools, where the underlying objective is for member firms to cross-license useful technologies efficiently, the goal of patent aggregators is often to capture the exclusion value of a patent. Rent seeking through the patent system has created significant payoff opportunities to firms that hold patents without the intention of commercializing. A prominent example is BlackBerry maker Research in Motion's $613 million settlement for the infringement of patents held by the patent aggregator NTP. Patents can induce an unproductive misallocation of resources away from invention and towards litigation. This is a more general problem if the structure of payoffs in an economy encourages rent-seeking activities.[59]

The way the current patent system rewards rent-seeking activities is a plausible explanation for the recent trend towards patent aggregation. For example, when Google acquired Motorola Mobility for $12.5 billion in 2012, it was at least partly motivated by Motorola's 17,000 existing patents and its pending

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[56] Ryan Lampe & Petra Moser, *Do Patent Pools Encourage Innovation? Evidence from the Nineteenth-Century Sewing Machine Industry*, 70 J. ECON. HIST. 898 (2010).

[57] Ryan Lampe & Petra Moser, *Patent Pools, Competition, and Innovation—Evidence from 20 U.S. Industries Under the New Deal* 29 (Stan. L. & Econ., Olin Working Paper No. 417, 2013), *available at* papers.ssrn.com/sol3/papers..cfm?abstract_id=1967246.

[58] Nancy T. Gallini, *The Economics of Patents: Lessons from Recent U.S. Patent Reform*, J. ECON. PERSP., Winter 2002, at 131, 144.

[59] Institutions and laws powerfully affect the structure of payoffs and the allocation of entrepreneurial activity between productive, unproductive, and destructive pursuits. *See* William J. Baumol, *Entrepreneurship: Productive, Unproductive and Destructive*, 98 J. POL. ECON. 893 (1990).

patent applications. Aggregation of large patent portfolios may be justified in response to the potential payoffs that arise from holding intellectual property on a collection of knowledge assets, or the perception that acquisition costs are significantly less than litigation costs. But in the latter case, if patents are being aggregated in costly ways purely to defend against litigation (i.e., defensive aggregations), this may stifle further investment in developing the technology areas affected. While offensive aggregators, who acquire patents in order to assert them against companies, are typically considered to be more damaging to innovation, both offensive and defensive aggregations can potentially reduce welfare.

IV. POTENTIAL SOLUTIONS

If patents can be stifling to innovation, then what are the options available to policy makers? In part the solution is to reform the existing patent system. Adam Jaffe and Josh Lerner offer a set of prescriptions.[60] In particular, they caution against the issuance of weak patents, which increase the susceptibility of genuine inventors to litigation. Furthermore, the negative effect is multiplicative since high litigation costs can constrain individual entrepreneurs and startup firms, which typically act as one of the main drivers of economic development. Among their other suggestions are using judges rather than juries in patent suits to improve objectivity. They also suggest shifting from a "first-to-invent" to a "first-to-file" rule.[61] This latter suggestion has been implemented as part of the America Invents Act of 2011, which aims to make the patent system more efficient and avoid unnecessary litigation surrounding the determination of priority.[62]

In addition, it is possible to complement patents with mechanisms that can also incentivize innovation without some of the static costs associated with patents. Michael Kremer and Heidi Williams explain that the toolkit available to policy makers has expanded far beyond conventional IP rights. For example, Advance Market Commitments (AMC) could correct for some of the defects of patents, especially in instances, such as a technology for providing clean water in developing countries, where the invention has high welfare benefits to users but low private returns to inventors. The AMC works by offering a contract where sponsors (e.g., governments or benevolent individuals) pay for a new technology in advance of its development. By guaranteeing a market price for the new technology, as paid for by the sponsor, in return for

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[60] JAFFE & LERNER, *supra* note 9, at 163–68.

[61] *Id.*

[62] 35 U.S.C. § 102.

caps on the price at which the new technology is used by consumers, inventors have incentives to engage in R&D and the welfare benefits are realized.[63]

Prizes offer a similarly powerful inducement to potential innovators without the deadweight losses associated with patents. The underlying logic is that patents, by providing a temporary monopoly, lead to prices being set at a level that excludes certain buyers who would otherwise consume at the competitive market price. Prizes remove this pricing distortion by offering inventors a payment to compensate them for the absence of a patent and then placing the new technology in the public domain at the marginal cost price. For example, Michael Kremer's patent buyout mechanism compensates inventors using a public auction to establish the private value of a technology. Inventors are fully incentivized to develop new technologies as the government commits to paying a markup over the private value, which provides a source of supernormal returns.[64] Although the government would need to fund the buyout using tax revenues, the deadweight loss is, in principle, less than under a patent because it is spread out across a larger number of consumers.[65]

Although prizes are often touted as a substitute for patents, in practice prizes are typically offered in complementary settings to patents. Liam Brunt, Josh Lerner and I present an historical analysis of 1,986 prizes for agricultural inventions that the Royal Agricultural Society awarded in England between 1839 and 1939 when patents were also available. We find that prizes provided a significant boost to innovation. Prizes appear to have caused a net increase in technological development, because this effect cannot be accounted for by inventors re-directing their efforts from non-prize to prize technology areas. Furthermore, our study finds that non-monetary prizes (i.e., prestigious medals) were especially effective. This suggests that these types of prizes can be a cost-effective method for providing innovation incentives.[66]

Building on this line of research, I have used data from Meiji Japan between 1885 and 1911 (when patents were also available to inventors) to show that prize competitions encouraged technological development, dialogue between inventors about best practice techniques, and the diffusion of new ideas. Again most of the rewards offered were non-monetary.[67] According to further work by Petra Moser and me, publicity for promising research fields is

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[63] Michael Kremer & Heidi Williams, *Incentivizing Innovation: Adding to the Tool Kit*, *in* 10 INNOVATION POLICY AND THE ECONOMY 1 (Josh Lerner & Scott Stern eds., 2010).

[64] Michael Kremer, *Patent Buyouts: A Mechanism for Encouraging Innovation*, 113 Q.J. ECON. 1137, 1138 (1998).

[65] Heidi Williams, *Innovation Inducement Prizes: Connecting Research to Policy*, 31 J. POL'Y ANALYSIS & MGMT. 752, 757 (2012).

[66] Liam Brunt, Josh Lerner & Tom Nicholas, *Inducement Prizes and Innovation*, 60 J. INDUS. ECON. 657 (2012).

[67] Tom Nicholas, *Hybrid Innovation in Meiji Japan*, 54 INT'L ECON. REV. 575 (2013).

an important mechanism by which prizes encourage innovation. We come to this conclusion by comparing patenting in technology areas where U.S. inventors won prizes for exceptional innovations at the Great Exhibition in London in 1851 with technology areas associated with lead articles in the *Scientific American*, a major, and widely distributed, science journal of the time.[68]

Evidence on the utility of prizes extends beyond historical research. For example, using modern data from TopCoder, a company that creates contests and prize rewards for software solutions for IT-intensive organizations, Kevin Boudreau, Nicola Lacetera, and Karim R. Lakhani show how innovation contests can be optimally designed to foster incentives and creative solutions.[69] They pay particular attention to the number of competition participants. Above some threshold too many participants tends to reduce effort on average, but at the same time a large number of participants increases the chance that a solution in the tail of the distribution will be found. They show that a lot depends on the type of solution being addressed by the contest. If the problem is a highly uncertain one, contests with many participants are preferable given the attractiveness of a long-tail solution. Alternatively, for less uncertain problems, smaller pools of participants work better as this is more likely to create an effort-inducing environment.

Policy makers have responded to growing evidence that non-patent based mechanisms can work. Under the 2010 America COMPETES Reauthorization Act,[70] Federal agencies such as the National Science Foundation have the power to sponsor prizes for exceptional innovations. According to the details of the new legislation, agencies are permitted to "use both Federal appropriated funds and funds provided by the private sector in order to design prizes, administer prizes, and offer monetary awards for prize competitions."[71] Overall, these types of policies are being designed to address the many defects associated with patents.

V. CONCLUSION

Patent laws have been a feature of American economic development for more than two centuries and it seems likely that, despite their limitations and

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[68] Petra Moser & Tom Nicholas, *Prizes Publicity and Patents: Non-Monetary Awards as a Mechanism to Encourage Innovation*, 61 J. INDUS. ECON. 763 (2013).

[69] Kevin J. Boudreau, Nicola Lacetera & Karim R. Lakhani, *Incentives and Problem Uncertainty in Innovation Contests: An Empirical Analysis*, 57 MGMT. SCI. 843 (2011).

[70] America COMPETES Reauthorization Act of 2010, 111 Pub. L. No. 358, 124 Stat. 3982 (2010).

[71] MEMORANDUM FOR GENERAL COUNSELS AND CHIEF INFORMATION OFFICERS FOR EXECUTIVE DEPARTMENTS AND AGENCIES, PRIZE AUTHORITY IN THE AMERICA COMPETES REAUTHORIZATION ACT 2, cio.gov/wp-content/uploads/downloads/2012/09/Prize_Authority_in_the_America_COMPETES_Reauthorization_Act.pdf.

imperfections, patents will continue to be the cornerstone of the IP legal architecture into the future. Nevertheless, laws relating to this critical policy area should be constantly refined and revised to offer greater flexibility in the face of rapidly changing industry circumstances and current patterns of technical change. Getting innovation incentives right is essential for encouraging technological development and the process of economic growth.

Among the many challenges facing policy makers, addressing the current trend towards patent aggregation is clearly an important one. Navigating the IP thicket has become complex, and it is reasonable to assume that it will become increasingly so. Patent aggregation is, to some degree, a self-reinforcing process. As ever larger patent portfolios are accumulated for offensive and defensive purposes, the demand for intermediaries like Intellectual Ventures to facilitate the allocation of IP resources will increase. A major concern is the extent to which patent aggregators are creating an unnecessary need to resort to intermediaries by complicating market transactions. If so, their activities distort markets rather than facilitate their efficiency.

Patent aggregators typically assume that patents are synonymous with innovation. However, a review of the literature suggests that patents provide only a blunt instrument for incentivizing innovation. One solution to the patent aggregation problem, which would improve the innovation incentives framework more generally, would be to reduce the reliance on patents, especially in knowledge intensive information technology areas where patent aggregation is particularly acute. As the number of alternative mechanisms to patents, such as AMCs, contests, and prizes has increased, so too should the willingness to experiment with these different options to test the viability of complementary mechanisms. A conscientious effort to align IP policy with variable incentives may help to avoid the suboptimal use and abuse of the patent system.