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THE BATTLE OVER PATENTS:
HISTORY AND THE POLITICS OF INNOVATION

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ABSTRACT

This essay is the introduction to a book of the same title, forthcoming in summer of 2021 from Oxford University Press. The purpose is to document the ways in which patent systems are products of battles over the economic surplus from innovation. The features of these systems take shape as interests at different points in the production chain seek advantage in any way they can, and consequently, they are riven with imperfections. The interesting historical question is why US-style patent systems with all their imperfections have come to dominate other methods of encouraging inventive activity. The essays in the book suggest that the creation of a tradable but temporary property right facilitates the transfer of technological knowledge and thus fosters a highly productive decentralized ecology of inventors and firms.

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> There are a considerable number of patents issued annually from the Patent Office which are of no force or value except for black-mailing and for interfering with the business of parties competing with their owners.
>
> [These patents] do not cover practical machines, but contain principles upon which other more practical inventors have buil[t], and which are infringed by the other patent devices, and are good for nothing except to be bought and speculated upon by those who are justly called patent sharks ….
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> —J. H. Raymond, Secretary and Treasurer of the Western Railroad Association

Were it not for his use of the word "shark" instead of our more familiar term "troll," J. H. Raymond might be taken for someone complaining about the patent system in the present day. The quotations, however, come from testimony he gave before the Committee on Patents of the US Congress in the 1870s (US Senate 1878, pp. 123, 230). Raymond was lobbying (unsuccessfully, it turned out) for a bill to reform the patent system and cure it of the evils inflicted on the public by the "curse" of worthless patents. Whatever problems Raymond attributed to the Patent Office's granting of "about fifteen times as many patents as ought to issue," the failure of the reform effort did not prevent the United States from embarking on the half century of rapid technological progress known as the Second Industrial Revolution. Nor did it prevent the US from rising to world leadership in such new technologically advanced industries as electricity, steel, telecommunications, and automobiles.[1]

As Raymond's testimony suggests, complaints about the patent system—and about how it could be abused to the detriment of legitimate businesses—are nothing new. Indeed, virtually all the sources of market friction that critics seize upon today as pretexts for patent reform ("patent thickets," "patent trolls," "patent holdup," "excessive patenting," and so on) were raised as matters of concern in the nineteenth century. These complaints have resurfaced again and again for the simple reason that the issues that underpin them have enormous consequences for the distribution of the producer surplus from innovation. Basically stated, producer surplus is the sum total of all the profits earned by the firms that make up the production chain for a good or service.[2] Innovators create surplus by developing new products that consumers want to buy or by devising new ways to make existing products more cheaply, but ultimately the total amount of surplus available to producers is determined by consumers' demand for the final good or service. Regardless of whether or not they are innovators, firms at the end of the production chain—that is, those that sell the final good or service to consumers—want to retain as much of the producer surplus as they can. Firms further up the chain, from the producers of raw materials to those that make intermediate inputs, also want as much of the surplus as they can get, regardless of whether they are innovators. Every firm in the production chain battles over the surplus, and they fight

[1] The patent reform bill proposed, among other things, to institute renewal fees for patents, impose a statute of limitations on infringement suits, and limit the damages that could be claimed for infringement. See US Senate (1878), pp. 1-9. The additional quotations from Raymond's testimony are from pp. 110 and 123. On the failure of the legislation in Congress, see Usselman (1991). On the Second Industrial Revolution in the US, see Mowery and Rosenberg (1989).

[2] Economic surplus emerges from the purchase by consumers of a good or service that they value. It is divided into producer surplus and consumer surplus. Consumer surplus is the difference between the maximum price a consumer is willing to pay and the price that the consumer actually pays. Aggregate consumer surplus is the sum of the consumer surplus for all individual consumers. Producer surplus is the amount that producers benefit by selling a good or service at a market price that is higher than the lowest price that they would accept.

with all the arrows in their quivers, including lobbying to change the laws governing patents. As a general rule, firms that develop the innovations that create surplus tend to lobby for stronger patent laws, because stronger property rights improve their negotiating position vis à vis businesses in the rest of the production chain. The other firms in the production chain, by contrast, tend to lobby for weaker patent laws in order to improve their negotiating position.

J. H. Raymond's gripes about worthless patents illustrate this point. Raymond was Secretary and Treasurer of the Western Railroad Association, the organization that coordinated the railroads' legal defense against patent suits, served as a clearing house for information about patents of interest, and (with its sister organization for eastern railroads) lobbied for patent reform (Usselman 1991). He certainly had cause for his complaints; railroads across the country were facing expensive lawsuits from people who bought up patents with the aim of forcing deep-pocketed businesses to pay licensing fees. The lawsuits filed by these "sharks" generated outrage in the late nineteenth century for much the same reason as those brought by "patent trolls" today, and Raymond's protests about the sharks' exploitation of worthless patents allowed him to build support for the railroads' proposed reforms.[3]

Ultimately, however, Raymond was after bigger game—namely, the firms and entrepreneurs whose valuable patents gave them a claim on the railroads' revenues—and he used the House and Senate hearings to take swipes at them. Belittling George Pullman's achievements, for example, Raymond asked rhetorically, "Why should Mr. Pullman, by reason of having a patent on the triangular space in the roof for the upper berth, which is his most

[3] The most notorious example of lawsuits targeting railroads involved a series of overlapping brake patents. Railroads that bought licenses for one or another of the patents found themselves sued for infringement on the others, all of which were for a time owned by one Thomas Sayles. See Usselman (1991), pp. 1062-64; and Usselman (2002), pp. 108-17. Sharks also generated outrage by targeting farmers and other end users of patented items. See Hayter (1942 and 1947) and Magliocca (2007). For an example of current hostility toward "trolls," listen to the podcast "When Patents Attack!" from the series "This American Life," https://www.thisamericanlife.org/441/transcript (accessed 12 December 2020).

important patent, the validity of which is least questioned, prevent the railroad companies from using any kind of sleeping cars that the public accept?" He went on to imply that George Westinghouse's patents were a crime against humanity. "[W]hy should we be obliged to buy any power-brake of Westinghouse or Lockridge or Eames or Smith, and, in order to be able to protect the lives and property of the people, pay them $150 for what it costs then $10 or $12 to make in the first instance …?" (US Senate 1878, p. 115).

Many business people, of course, were on the other side of this debate. They benefited from patent protection and objected that the proposed legislation would drastically limit their ability to enforce their intellectual property. Patentees who testified at the hearings complained that the "inventors of this country have not been represented" in the drafting of the bill. As W. Wheeler Hubbell, an inventor and lawyer, charged, "This whole thing is got up to facilitate the infringement of patents, and it is got up by infringers" (US Senate 1878, pp. 158, 162). *Scientific American*, whose editors considered themselves spokespersons for inventors, came out against the bill, decrying it as an attempt by the railroads to establish a legal process for confiscating intellectual property. Under the guise of declaring inventions that had an obvious utility to be "worthless," the railroads sought to use for free technology that they would otherwise have had to pay to license.[4]

The witnesses who testified at the Patent Committee's hearings in the late 1870s were exclusively parties with practical experience with patents: inventors, representatives of the railroads and other patent users, attorneys who handled infringement cases, and officials from the

[4] "Wanted: A Legal Process for Confiscating Inventions," *Scientific American*, Mar 16, 1878, p. 16. See also, "The Proposed Emasculation of the Patent Law," *Scientific American*, Apr. 13, 1878, p. 224; "Arguments for Section 11," *Scientific American*, May 11, 1878, p. 288; "A Raid on Inventors' Rights," *Scientific American*, May 18, 1878, p. 304; "The Discouragement of Invention," *Scientific American*, Aug. 17, 1878, p. 97; "An Amendment to Discourage Invention," *Scientific American*, Dec. 28, 1878, p. 401.

Patent Office (US Senate 1878, p. 13). In recent years, however, another group has figured prominently in the list of experts that policy makers consult about problems with the patent system: academics. For example, the hearings conducted in 2008 and 2009 by the Federal Trade Commission (FTC) on reforming the patent system included more than thirty witnesses with academic appointments, about a quarter of the total, and the hearings themselves were hosted by the University of California, Berkeley (US FTC 2011, pp. 280-91). Scholars are sought today as witnesses precisely because they are not practitioners. Because they are not directly involved in the contest over the surplus, the hope is they can provide more objective advice about how to improve the workings of the patent system.[5]

Most of the academics who have participated in recent debates about the patent system are economists and legal scholars whose work is either highly theoretical or based on the analysis of very recent experience. Despite the contemporary focus of their research, they often attempt to validate their claims about problems with the patent system by invoking historical experience. And when they do, they just as often fall into errors—accepting uncritically claims made by interested parties, repeating older allegations in the secondary literature that historians have discounted or outright rejected, and/or proclaiming that some source of market friction in the patent system today is unprecedented when in fact it has a long history and may even have taken a more extreme form in the past.[6]

It is important, of course, to correct such basic errors, but getting the history right involves much more than that. It requires scholars to examine critically the claims about the patent system made by actors in the past, situate those claims relative to the disputants' places in

[5] Of course, there is still always the worry that scholars are not truly disinterested but are working for participants.

[6] Examples include Boldrin and Levine (2008), Jaffe and Lerner (2007), and Kramer (1998). For critiques of these works, see Bottomley (2014), Beauchamp (2016), and Khan (2015).

the production chain, and understand the political environment in which claims were made and adjudicated. The essays in this volume take up this challenge and thus enable us to see the patent system as a very human creation, the product of contending interests battling over surplus in specific economic and political contexts that varied over time and across different locations.

Like all human creations, patent systems are necessarily riven with imperfections. As Adam Smith (1776) noted, it is a natural human tendency to barter, truck, and trade. As he also made clear, however, bartering, trucking, and trading arise not from the goodness of human hearts, but from self-interest. That same self-interest means that human beings will use markets for law and politics, as well as the economic marketplace, to achieve their goals. They will search out, generate, and exploit any and all sources of friction as they battle over economic surplus, and, the larger the potential surplus, the more extreme will be their efforts. Imperfections, in short, are an inherent feature of *any* system that is designed to generate and apportion economic surplus. Nirvana is not on the menu of available options.

What Is the Question to Which Patents Are the Answer?

The most interesting intellectual issue, therefore, is not how patent systems are imperfect, but why historically they have come to dominate all other methods of encouraging inventive activity. To answer that question one must first ask how patents work to stimulate technological discovery. The answer most commonly given—that they reward inventors by granting them a temporary monopoly for the technologies they develop—is, to say the least, misleading. A patent is a right to exclude others from using a particular technology, but the extent to which that right also confers market power depends on the existence of potential substitutes. At one extreme, if there are no substitutes for the technology and if it cannot be reverse engineered, there is no incentive for an inventor to patent. To secure a patent, an inventor has to reveal information about how the technology works that others can use against her after the term of the patent expires. The inventor would be better off if she kept the discovery as a trade secret and used her proprietary knowledge to dominate the market. The result would be a monopoly, but one that had nothing to do with patents. If the technology can be reverse engineered, however, then the breadth of the right to exclude conferred by the patent can affect the availability of substitutes. Historically, patents for inventions that examiners considered to be path breaking might receive the designation "pioneer" invention and thus obtain property rights that were broader scope than most other patents. In addition, under the legal doctrine of "equivalents," a producer whose technology did not literally infringe on a pioneer patentee's claims might nonetheless be found guilty of infringement if the technology performed "substantially the same function in substantially the same way to obtain the same result."[7] Not surprisingly, securing the designation pioneer patent was an important way in which inventors sought to increase their share of the producer surplus. The value of the label should not be overstated, however, as pioneer patents still often faced substitutes from competing technologies. To give an obvious example, holders of the basic aluminum smelting patents might have been able initially to exclude others from producing the same metal, but they still had to compete for business with producers of steel (Smith 1988).

Patents are valuable to inventors for two reasons. First, the right to exclude protects them against competitors seeking to free-ride on their ideas. Second, the right to exclude takes the form of a temporary property right that can be sold, licensed, and traded. Most technologically

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[7] *Sanitary Refrigerator Co. v. Winters*, 280 U.S. 30 (1929) at 42, quoted in Love (2012), p. 388. However, according to Love (p. 388, n. 27), suits brought for literal infringement of the claims were more likely to be successful.

creative people are eager to profit from their discoveries (Sokoloff 1988; Khan and Sokoloff 1993); even those who just enjoy inventing for its own sake need to earn revenues in order to keep doing what they love. Inventors are not always good at running businesses, however, so they often prefer to transfer the task of commercialization to others whose abilities are better suited to that activity. This transfer can occur within a firm, as, for example, when inventors in an R&D department develop technologies used in products that are manufactured and marketed by other units in the same firm. Or inventors can set up their own R&D firms, as Thomas Edison did with Menlo Park, with the aim of selling or licensing their patents to other enterprises better placed to exploit them.[8] Either way, inventors need assurances that their discoveries will not be appropriated without compensation: those inside a manufacturing firm need their accomplishments to be legally recognized to insure they feed into salary negotiations; those outside a manufacturing firm need to be able to reveal enough information about their discoveries to close a licensing deal or a sale without fearing that their ideas will be stolen. The temporary property right that comes with a patent grant provides the requisite assurance, facilitating a division of labor in which inventors can specialize in what they do best.[9]

The same temporary property right that enables inventors to specialize in invention also makes it possible to assemble the numerous technologies needed to produce complex products (Kieff 2006). Most products are not themselves patented; what are patented are the technologies that make the products possible. Many people reading these words are doing so on a laptop computer, a tablet, or (eyesight permitting) a smartphone. There is no patent for a laptop, tablet,

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[8] Edison set up companies to exploit some of his patents, but he was a poor businessman and typically ended up fighting with his financial backers, most notably J. P. Morgan. He was most productive at patenting when he was not involved in business. The great inventor Elmer Sperry had a similar experience. See Israel (1998) and Hughes (1971).

[9] This point about the gains from specialization goes back as far as Smith (1776), while its specific application to invention goes back at least to Arrow (1962). For a historical application, see also Lamoreaux and Sokoloff (1999 and 2007) and Lamoreaux, Sokoloff, and Sutthhiphisal (2013).

or smartphone. Rather, there are tens of thousands of patented technologies that are embedded in these devices and allow readers to download this book, display the words on a screen, make notes in the margins, share their thoughts with other readers—and do all of these things regardless of the type and brand of device they own. Most of these patented technologies were not developed by the firm whose brand name appears on the device. They were developed by specialized firms, many of which do not manufacture any part of the device but instead focus on developing the technologies that permit the parts and the whole to function.

Basic economic logic suggests that the patents held by these specialized firms do not confer monopolies. A monopoly allows a firm to restrain output and raise the market price. If you have ever purchased a hot dog at a baseball game or a bag of popcorn at a movie theater, you have had first-hand experience with monopoly pricing, and you know that the stadium or theater can maintain its monopoly because there are no substitutes. You cannot grill your own hotdogs in the stands or pop your own popcorn at the multiplex. Nor can you turn to competing suppliers. A direct test for the existence of a monopoly, therefore, is to look at the prices charged. If any of the firms that owns the patented technologies in your laptop, tablet, or smartphone is a monopolist, the royalty paid by the manufacturer to the patent owner would reflect that monopoly, and the manufacturer would pass it along to you. Simply put, laptops, tablets, and smartphones would be priced in much the same way as movie theater popcorn. That prediction does not square, of course, with the fact that the prices for these devices have been falling like stones for years and are now so low that parents give them as toys to children (Galetovic, Haber, and Levine (2015). To be sure, you can pay over a $1,000 for a top of the line Apple iPhone. But for Christmas 2020 you can also buy a low-end iPhone on Amazon for around $250 and you can get perfectly serviceable smartphones from reputable companies like

Nokia and Samsung for substantially under $100.[10] $100 is roughly one-hundredth the inflation-adjusted cost of the mobile phone introduced by Motorola in 1983—a 1G phone that had no data or texting capabilities, was the size of a brick, weighed a kilo, and had a battery that lasted for half an hour (Galetovic, Haber, and Zaretzki 2017).

The patents as monopolies hypothesis would also predict that the owners of the patents in the smartphone production chain would capture a huge portion of the revenues generated by smartphone sales. In order to test that prediction against evidence, Alexander Galetovic, Stephen Haber, and Lew Zaretzi (2018) compiled data on total licensing revenues for the main holders of patents used in smartphones in 2016 and compared them to the value of all smartphones shipped that year. They calculated that royalties on patents accounted on average for 3.4 percent of the value of these phones. Even adding in generous estimates of royalties paid to less important patent holders not included in the data and taking into account the possibility that some firms were able to evade paying royalties on the phones they shipped, the estimate rises only to 5.6 percent. Galetovic, Haber, and Zaretzi (2017) also parameterize a model, based on actual smartphone prices and number of units sold and estimate t that a single patent holder acting as a monopolist would have charged a royalty equal to roughly two-thirds of the value of the average smartphone, and that had all of the patent holders in the smartphone production chain acted as independent monopolist they would have charged a royalty equal to roughly 80 percent of the value of the average smartphone. In short, the actual royalties paid to patent holders in the smartphone industry are an order of magnitude lower than the royalties predicted by the

[10] See https://www.t3.com/us/news/best-cheap-smartphone; and https://www.amazon.com/s?k=inexpensive+smart+phone&ref=nb_sb_noss_2 (accessed 13 December 2020).

hypothesis that patents confer monopolies. Moreover, because the higher royalties would have been passed on to consumers, the price of phones would have been much higher.[11]

The falling price of electronic equipment has often been attributed to what is known as Moore's law, the observation made by Intel co-founder Gordon Moore that the number of transistors on a chip doubles every two years while the costs per transistor are halved. The implication is that the falling prices of high tech-products, such as smartphones, have occurred for technological reasons having nothing to do with the patent system. However, as Galetovic notes in his chapter in this volume, "Patents in the History of the Semiconductor Industry: The Ricardian Hypothesis," Moore's Law is not a law of nature, like the speed of light, but is a rule of thumb about an empirical regularity that has been observed in a particular institutional context. The validity of Moore's law depends on certain physical properties of silicon, the material out of which chips are made, but those properties alone are not sufficient to explain the relentless improvement in quality and decline in price. What enabled the semiconductor industry to accomplish this feat was the emergence of a productive division of labor between chip manufacturers and the myriad of small design firms that developed integrated circuits for specialized uses.

Galetovic details how this vertically disintegrated structure emerged in the early 1980s as a consequence of fundamental technological advances, and how patents played a key role in making the division of labor possible. As the industry became increasingly decentralized, the number of patents soared from about 400 semiconductor patents per year in the 1960s to 10,000 per year in the 2000s to more than 20,000 per year today. Chip designs are simple to reverse

[11] Galetovic, Haber, and Zaretzki (2017) estimate that a single patent-holder acting as a monopolist would have driven up the average price of a smartphone from $281 to $816. If all patent holders had acted as monopolists, the price of a smartphone would have been higher still, $1,320—almost five times the actual average market price. For further evidence on this point, see Galetovic and Haber (2017 and 2021).

engineer, so firms can easily free ride on other firms' investments in technology, copying their designs without incurring the R&D costs. However, if the means of achieving electronic functionality in a chip is patented, other firms cannot use it for free; they must bear the R&D costs of inventing around the patent, or alternatively purchase or license it. Design firms derive their revenues mainly from the licensing royalties they charge users of their designs, but the rich abundance of capable design firms that this property-rights environment supports means that substitutes are always at hand, keeping royalty rates relatively low. Because patents allowed semiconductor firms to behave as if free riding did not exist, the industry was able efficiently to adjust its horizontal and vertical structure to fit its developing technology.

One implication of Galetovic's analysis is that patents do more than give inventors a claim to a share of the economic surplus generated by a consumer good that makes use of their invention. They also facilitate the transfer to others of the non-patented knowledge necessary to produce that good. The owner of the patent cannot earn royalties if the end user is unable to make the technology work, but the patentee will be reluctant to supply the necessary knowledge in the absence of a secure property right (Arrow 1962). This point is explored by Victor Menaldo in his chapter, "Do Patents Foster International Technology Transfer? Evidence from Spanish Steelmaking, 1850-1930." Menaldo's central point is that not all of the information necessary to turn a patented technology into a commercially viable product can be imparted in a patent's written description; much of it remains tacit. Unless the firm or individual that initially developed the technology, and thus holds the patent, cooperates by providing drawings, blueprints, machinery, tutorials, and training, the patented technology cannot be used effectively by a firm further down the production chain. Patents thus allow firms at different points in the chain to align one another's incentives. A patent allows Firm A to show Firm B exactly how to produce a good or service, using both Firm A's patented technology and its vast store of unpatented knowledge; but that tacit knowledge is made available to Firm B only if it pays for the patented technology.[12]

It follows, therefore, that patents are also an important part of the answer to the question of how a technologically laggard country can catch up with the rest of the world. A patent system gives firms in, say, Country X a claim on the use of their technologies by firms in Country Y—provided that Country Y has a patent system that allows foreign firms to patent the technologies they developed (and patented) in their home country. Because the use of those technologies by firms in Country Y produces a flow of licensing royalties to the firms in Country X, the firms in Country X have an incentive to transfer their tacit knowledge to the firms in Country Y. Without a patent system in Country Y, however, there will be no incentive for Country X firms to transfer any of that knowledge. Firms in Country Y will have to operate with antiquated technologies.

Menaldo illustrates this general principle through a detailed examination of the role of patents in the transfer of technology to the Spanish steel industry over the course of nearly a century. Steel making is the quintessential example of an industry in which a substrate of tacit knowledge was (and is) a necessary input to production: turning hunks of rock into steel shapes requires an intricate ballet of ores, fuels, furnaces, rolling mills, and human beings. Most of the knowledge about how to perform this ballet could not be conveyed in a written description. Like an actual ballet, its performance requires practice under the tutelage of experienced teachers. Without knowledge about how small differences in temperature, timing, or the chemical composition of ore affect steel qualities, rails would fracture under the stresses imposed by heavy

[12] The importance of tacit knowledge for the diffusion of technology has long been recognized in the literature, but most scholars have used this point to emphasize the insufficiency of patent disclosures and have failed to consider the importance of patents for facilitating other forms of communication. For a recent example, see Lee (2012).

trains, girders would sag under the weight of buildings, and ships would leak because hull laminates would not align properly. Tacit knowledge was also necessary to economize on fuel costs and prevent damage to equipment from repeated heating and cooling. Thus, the central theme of Menaldo's essay is that Spanish patent law facilitated the necessary transfer of knowledge as the technology of steel production changed over time, from the Chenot process to the Bessemer Converter to the Siemens Martin open hearth furnace. Patent licensing agreements not only gave Spanish manufacturers access to cutting-edge technologies developed by innovators elsewhere but also, by giving those innovators access to improvements made in the course of adapting their technologies to the ores and other special conditions of Spanish manufacture, increased knowledge about steel production in ways that furthered the transfer of steel technology to new settings.

Menaldo's chapter covers one industry in one country, but other scholars have come to similar conclusions for other locales. For example, Alexander Donges and Felix Selgert (2019) found that patents played an important role in transfer of technology to Germany in the late-nineteenth century. For the recent period, Shih-tse Lo (2011) has demonstrated the positive effect of an exogenously imposed set of patent reforms on R&D spending and patenting activity in Taiwan. Countries will of course vary in their capacity to innovate, depending on the extent of prior investments in the requisite types of human capital. The competitive structure of the global industry also affects the extent to which local firms can effectively exploit particular technologies. Thus scholars have obtained somewhat different results for different countries and industries at different points in time (see, for example, Qian 2007). However, the available cross-country quantitative evidence generally supports Menaldo's generalization about the importance of patent protection for the transfer of technology to developing countries (Chen and Puttitanun 2005; Branstetter, Fisman, and Foley 2006; Kim, Lee, Park and Choo 2012).

"Excessive Litigation," as Compared to What?

In contrast to Galetovic's argument about the importance of patents for spurring technological change, or Menaldo's about the role of patents in facilitating the diffusion of technology internationally, critics of the patent system point to cases where (at least so they claim) patent holders were able to block technological progress for considerable periods of time by suing competing inventors for infringement. An example is Michele Boldrin and David Levine's argument that steam-engine inventor James Watt and his partner Matthew Boulton aggressively used patents to suppress the supposedly better steam engine developed by Jonathan Hornblower. Because Hornblower's engine built on Watt's early work, "Boulton and Watt were able to block him in court and effectively put an end to steam engine development." Boldrin and Levine go so far as to assert that "[b]y keeping prices high and preventing others from producing cheaper or better steam engines, Boulton and Watt hampered capital accumulation and slowed economic growth" (Boldrin and Levine 2008, p. 4).

In his chapter in this volume, "Did James Watt's Patent(s) Really Delay the Industrial Revolution?" Sean Bottomley uses new archival research to demolish Boldrin and Levine's claim. Hornblower patented his steam engine in 1781 and actively marketed it to the same client base as Boulton and Watt. Yet Boulton and Watt did not take legal action against Hornblower until 1799, the year before their steam engine patent expired. The delay was partly because Boulton and Watt were able for a while to collect royalty payments from many purchasers of Hornblower engines that used their technology. But it was also because Boulton and Watt were reluctant to risk enforcing a patent they thought was legally vulnerable until forced to do so by engine users' growing reluctance to pay them royalties. Regardless, the important point is that Hornblower was able to develop his steam engine unmolested for nearly two decades, and when Boulton and Watt finally moved against him and won, he had only to wait for one more year before their patent expired.

Bottomley's analysis of the market for steam engines provides additional evidence against Boldrin and Levine's argument. In the late eighteenth century, engine manufacturers' most important customers were mine owners, who used the machines to pump water out of their shafts. Boulton and Watt convinced mine owners to substitute their engine for the more primitive Newcomen model then in use by setting their royalty rate at an amount equivalent to one-third of the fuel savings that resulted from using their new technology. They understood that they could not extract all or even most of the surplus generated by their engine and still get mine owners to buy it. Many of their competitors adopted essentially the same pricing strategy. Hornblower sought, however, to go them one better by pegging his royalties at one-third of his engines' fuel savings over the Boulton and Watt engine. Hornblower thus had every incentive to improve the efficiency of his engines, and every opportunity to do so during the nearly two decades in which Boulton and Watt left him alone. If, as Boldrin and Levine assert, he failed to produce an improvement over the Boulton and Watt engine, that failure was chargeable either his own ineptitude, the inherent difficulties of the task, or both—not to legal harassment by Boulton and Watt.

Even though Boulton and Watt held back from suing Hornblower for a long time, other patent holders in similar situations were not so restrained. By now, however, it should be obvious that litigation, or the threat of it, has strategic value in the battle over the producer surplus. To return to the examples of laptops, tablets, and smartphones, the owners of the patents that permit these devices to be compatible and interoperable often sue manufacturers for infringement, while manufacturers often sue the owners of those standard essential patents for breach of contract (for instance, for charging a royalty that is not FRAND—Fair, Reasonable, and Non-Discriminatory). Litigation is simply one negotiating tool among many others.

Critics of the patent system acknowledge this basic fact, but then frequently claim that the rate of patent litigation has recently become "excessive" (Bessen and Meurer 2008, ch. 6: Jaffee and Lerner 2007, pp. 13-16). Any statement about something being too high or too low necessarily implies a comparison: excessive, as compared to what? This question is taken up in Christopher Beauchamp's essay in this volume, "Dousing the Fires of Patent Litigation." Using a unique dataset of nineteenth-century patent lawsuits that he laboriously collected, Beauchamp shows that present-day patent litigation rates were dwarfed by the levels reached during the 1840s to 1880s. This fact holds true regardless of whether one scales the number of suits by the number of patents in force, the size of the economy, or the total caseload of the federal courts (Beauchamp 2016).

Although patent litigation rates were sky-high in the middle part of the nineteenth century, they fell dramatically during the final decades and remained at low levels from roughly 1900 to the 1980s. This drop occurred despite the failure of patent reforms (advocated, as we have seen, by the railroads) that would have made it more difficult to enforce patents against infringers. Legal changes were nonetheless an important part of the story. Patent systems must balance the incentive to invent that derives from the grant of a temporary property right against the possible discouragements to technological progress that the right to exclude might entail if patents are too broad or long-lived. Beauchamp shows that a large fraction of the litigated patents had been extended beyond their original term by Congress or the Patent Office, and that a great deal of the decline in litigation rates can be explained by statutory changes that phased out such extensions. Another large fraction involved patents that had been reissued after the original grant. Patentees were increasingly using the reissue process to broaden the scope of their patents ex post and, in that way, transform competitors into infringers with the stroke of a pen. During the 1870s the Supreme Court reined in this practice. Patentees then had to be satisfied with their initial claims and take care to specify them with greater clarity.

Changes in the legal rules governing the patent system thus helped lower litigation rates during the late nineteenth century, but they were by no means the whole story. Beauchamp finds that changes in the organization of the economy contributed to the decline as well. Large horizontally and vertically integrated firms came to dominate many lines of manufacturing that previously had been the domain of small and mid-sized enterprises. As the number of firms in the production chain fell, there were fewer firms to sue, and the large firms that remained had the wherewithal to tie up potential litigants in the courts for years, making lawsuits a less attractive proposition. The change in the number and size distribution of firms also helped by reducing the collective action problems involved in achieving a negotiated settlement. Moreover, as R&D moved out of small, specialized firms and into the research departments of the new giant enterprises, independent inventors became employees, transforming the battle over the surplus from conflicts among firms into salary negotiations within large-scale enterprises.

In recent years, litigation rates have been increasing again (though not to anywhere near the levels Beauchamp observed for the mid-nineteenth century), and the large firms that are frequent targets of infringement suits have been lobbying for legislation to reduce the enforceability of patents, just as the railroads did in the late nineteenth century. One implication of Beauchamp's study is that policy makers should, before taking such a radical step, consider other ways in which changes in the law or legal doctrine may have increased the number of lawsuits. For example, much of the recent growth in litigation is an artifact of the 2011 America Invents Act (AIA), which altered the rules regarding "joinder" (the practice of including multiple defendants in a single lawsuit). By raising the standards for joinder, the AIA increased the number of lawsuits filed: if different defendants with different products could no longer be joined to the same suit, plaintiffs simply filed more suits, one for each defendant. Other recent changes, such as the reorganization of the courts to create a centralized Court of Appeals for the Federal Circuit (CAFC) to hear patent cases, may also have contributed to the number of lawsuits (Jaffe and Lerner 2007). Bessen and Meurer's list of potential causes for the recent growth in litigation includes an increase in the practice of filing what are called "continuing applications." Like nineteenth-century reissues, this practice allows patentees to alter their claims after the initial application, making it more difficult for competitors to know what constitutes infringement (Bessen and Meurer 2008, 62-63, 150-151).

Another implication of Beauchamp's study for the current debate over excessive litigation is that changes in the structure of the economy can affect the amount of litigation. Just as the late-nineteenth-century rise of large firms with in-house R&D laboratories reduced the number of patent lawsuits, the declining power of these kinds of enterprises in the late twentieth century may have reversed that trend (Lamoreaux, Raff and Temin 2003). As large firms began to cut their research budgets and acquire more of their technology from outside, their share of non-federal R&D expenditures dropped from about two-thirds in 1980 to only about one-third in 2005, while the share of small- and medium-sized firms (SMEs) increased commensurately

(Arora and Gambardella 2010).[13] The mid-nineteenth century litigation explosion took place during a period when American manufacturing was characterized by large numbers of highly specialized SMEs engaged in the development of new second-industrial-revolution technologies. The parallel to the present-day is striking. Most of the patent lawsuits filed today involve high-tech firms, and as Galetovic shows for the semi-conductor industry, the tech sector is characterized by some very large firms but also large numbers of highly specialized SMEs.

Finally, Beauchamp's work reminds us that there is no relationship between litigation rates, innovation, and economic growth. The mid-nineteenth century period of high litigation was a period of extraordinarily rapid innovation and industrial expansion. The equilibrium outcome that is of interest to the public is not the number of lawsuits but rather the standard of living. If the creation of new products that continually improve in quality and fall in price is generated by a system in which small and mid-sized firms at the front end of a production chain bargain with larger firms further down that chain through patent litigation, it is naïve to think that one could eliminate the lawsuits without altering the production chain. One likely outcome would be the integration of R&D and commercialization into a much smaller number of very large firms, as occurred in the early twentieth century. That is, the reduction of lawsuits might come at the expense of an increase in vertical and horizontal concentration.

The Political Reshaping of the Patent System

Congress created the CAFC in 1982 in an attempt to put an end to forum shopping by patent holders and foster the development of a uniform set of legal rules for patent suits across

[13] Federal R&D expenditures (which disproportionately went to large firms with R&D labs) were also dropping in relative terms, from a peak of about two-thirds in the mid-1960s to about 30 percent in 2005 (Dworin 2015).

the country. Prior to 1982 appeals involving patent cases were heard by each of the regional federal circuit courts of appeal. That system had been set up by the Judiciary Act of 1891 in order to reduce the burden of cases of all types on the U.S Supreme Court.[14] In the area of patents the act accomplished its purpose very well; after 1891 the Supreme Court only rarely heard appeals involving patents. But the resulting lack of judicial oversight meant that the regional appeals courts had considerable leeway to interpret patent law as they saw fit, with some demonstrating a greater propensity than others to enforce patent rights. According to Adam Jaffe and Josh Lerner (2007, p. 100), for example, during the third quarter of the twentieth century judges in the Tenth Circuit (based in Denver) found against infringers nearly 60 percent of the time, whereas in the Eighth Circuit (based in St. Louis) the equivalent figure was less than 10 percent.

Steven Usselman's chapter, "Ninth Circuit Nursery: Patent Litigation and Industrial Development on the Pacific Coast, 1891-1925," analyzes the uses to which appeals-court justices put their autonomy in the third of a century following the Judiciary Act. Focusing on the Ninth Circuit, which included the rapidly growing economy of California, Usselman exploits a treasure trove of nearly 1,500 volumes of appeal documents, including trial transcripts, briefs, and exhibits. These documents allow him to reconstruct all 148 patent cases for which the Ninth Circuit issued a formal ruling during this period. They also allow him to track whether the US Supreme Court considered the case on appeal, and if so, what the justices decided.

A superficial count of decisions of the type offered by Jaffe and Lerner would suggest that the Ninth Circuit was aggressively anti-patent, because the justices found in favor of

[14] The Judiciary Act of 1891 limited the categories of cases that could be appealed directly to the Supreme Court and at the same time created a system of regional circuit courts to hear cases on appeal from trial courts. It also eliminated the requirement of "circuit riding" by Supreme Court justices, under which the justices sat as trial judges on cases heard by federal district courts.

infringers most of the time. On closer examination, however, a more nuanced picture emerges. Many of the cases involving charges of infringement were brought by large national enterprises against small Western producers. Usselman finds that the court exhibited a strong regional bias in its decisions, ruling in ways that protected local firms from outsiders' claims of infringement at the same time as it strengthened local inventors' patent rights vis à vis the rest of the country. In this way, Usselman shows, the justices of the Ninth Circuit nurtured the growing California economy, allowing firms at the beginning of production chains to get a foothold in new technologies such as oil drilling and fruit processing, while protecting fruit growers, contractors, and other local firms at the end of production chains from claims of patent infringement by large, established firms in the East and Midwest. Within the region, the court pursued similar principles, bolstering technology firms in northern California while protecting end users of patented equipment in the southern part of the state from infringement suits.

There were, of course, limits to the Ninth Circuit's autonomy. The favoritism that it displayed toward firms within the region sometimes attracted the scrutiny of the US Supreme Court, particularly in cases where the judges had rather brusquely ruled against prominent national companies. Nonetheless, under the leadership of Chief Justice William Howard Taft in the 1920s, the general trend toward reducing the burden on the Supreme Court continued, and thus so did the regional decentralization of the patent system. Over time, moreover, the Ninth Circuit's bias in favor of small local producers received significant reinforcement as jurists' antipathy to large-scale enterprises grew under the influence of the antitrust movement.

That antipathy, as Jonathan Barnett shows in his chapter, "The Great Patent Grab," would eventually allow Justice Department officials to attack the use of patents by large-scale enterprises. Concerns about the problem of monopoly surged during the late 1930s when the economy, which by 1936 had seemed to be recovering from the Great Depression, collapsed for a second time (Hawley 1966). The most visible manifestation of the revival of interest in trust busting was a three-year investigation into the "Concentration of Economic Power," launched in 1938 by a specially created commission, the Temporary National Economic Committee (TNEC). The Committee began its hearings by examining large firms' use of patents to acquire market power and then held a second set of hearings to solicit ideas about how the patent system could be reformed (Hintz 2017). Thurmond Arnold, assistant attorney general in charge of the Justice Department's antitrust division, played a leading role in the hearings and the remedy he proposed was compulsory licensing—requiring firms to license their technology to anyone who wanted to use it. Although this recommendation made its way into the TNEC's final report, it did not go anywhere in Congress (Waller 2004). Yet, as Barnett shows, Arnold had already begun implementing it at the Justice Department. As early as 1938, for example, he put pressure on Alcoa to settle an antitrust suit by, among other things, opening up licenses on a particular set of patents. By the time Alcoa agreed to the arrangement in a 1942 consent decree, Arnold had already secured five other compulsory licensing orders. Many more were to come. Barnett has compiled a list of such orders from 1938 to 1975 and found as many as 133 of them. Although most of the decrees allowed firms to recoup some of their investment in the form of "reasonable" royalties, a third did not allow them to charge anything at all for the use of their intellectual property.

These compulsory licensing orders came at an unusual time in US history, when the federal government was playing a larger role in the economy than ever before and was financing an enormous amount of industrial R&D spending—fully two-thirds of the US total by the mid-1960s (Usselman 2014). Most of this funding went to large firms. In a sense, the government was giving with one hand and taking with the other—making decisions about the allocation of R&D funds in ways that encouraged economic concentration while pursuing novel antitrust policies to limit the monopolistic consequences of that spending. The result was as close to a managed economy as the US has ever had, and it involved the entire policy apparatus, including the courts. Thus compulsory licensing became a tool to manage market power even if there was no evidence that patents were being abused. In justifying the imposition of a licensing order on the United Shoe Machinery Company in 1953, for example, the Supreme Court admitted, “Defendant is not being punished for abusive practices respecting patents, for it engaged in none, except possibly two decades ago in connection with the wood heel business. It is being required to reduce the monopoly power it has, not as a result of patents, but as a result of business practices.”[15]

One of the implications of Barnett’s “The Great Patent Grab” is that public officials and judges are not robots programmed to maximize social welfare, but political actors responding to the environment in which they operate. As the conviction that government planning was superior to market coordination waxed during the late New Deal, support for the patent system waned. Antitrust officials were confident they could manage the extent of concentration in the economy. By weakening the patent system, they thought, they could encourage the entry of small firms, generate a more competitive market, and benefit consumers. As Barnett shows, however, this policy did not have the intended consequences. There was no decline in concentration. Large firms continued to dominate their respective product lines, relying on secrecy to protect their discoveries, enjoying access to abundant funding through defense procurement programs, and capturing the returns from innovation by integrating vertically rather

[15] *United Shoe Machinery v. U.S.*, 110 F.Supp. 295 (1953).

than contracting in the market with smaller enterprises. Investment in R&D grew as long as government provided the funding, but when federal agencies cut spending during the late 1960s, companies scaled back their R&D efforts commensurately. Not surprisingly, as faith in government's ability to manage the economy plummeted during the stagflation of the 1970s, compulsory licensing agreements fell into disfavor.

Stretching the Interpretation of the Rules

The creation and distribution of economic surplus necessarily entails a strategic interaction among firms—a game as it were—with the prize being a share of the producer surplus generated by a new product or an improvement to an already existing product. The laws that govern the patent system, as well as the courts and government agencies tasked with enforcing and interpreting the laws, set the rules of play. Companies can try to influence the formation of the rules, but as Barnett's chapter shows, there is an important level at which they have to take the rules as given and adjust their business strategies accordingly, shifting for example from patenting to secrecy and moving more activities out of the market and into the firm to prevent compulsory licensing from eroding their competitive advantage. Even in such a setting, however, it is in the interest of all the players battling over the surplus to try to stretch the interpretation of the rules in their favor.

Gerardo Con Diaz's chapter, "The Long History of Software Patenting in the United States," provides a case study of successful rule stretching. The targeted rule in this case was the so-called "mental steps doctrine," which held that any sequence of steps (for example, adding a column of numbers) that a human being with proper training could perform in his or her mind was ineligible for patent protection. As a practical matter, the mental steps doctrine meant that to be patent-eligible a process had to be implemented by a tangible machine or cause a transformation in something tangible. How, then, did it come to pass that something as intangible and inherently mathematical as computer code could be interpreted as patentable?

Con Diaz points out that when computers were first developed in the 1940s there was less of a distinction between the machine and the programs that controlled it than exists today. Programming, in fact, was a physical task that required operators manually to rewire circuits into new arrangements. The act of programming, therefore, did cause a transformation in something tangible. The great insight of the Bell Labs lawyers, who in 1948 wrote the first patent for a computer program, an error correction routine, was that they should not focus their claims on the novelty of the code itself, but on the specific way it enabled a machine made up of physical circuits to detect its own errors. The resulting patent, issued in 1951, was effectively granted for the computerization of a mathematical algorithm. Nonetheless, as Con Diaz shows, the decision to grant the patent was not at all controversial. It took two years for the lawyers to write the application but only one year for the Patent Office to approve it, and the examiners expressed no concerns whatsoever about the substance of the invention.

Once Bell Labs had performed this crucial stretching of what was patent eligible, other firms, such as the British Tabulating Machine Company (BTM), the International Business Machines Company (IBM), the Radio Corporation of America (RCA), and Texas Instruments adopted Bell's patenting strategy. Success with the patent office required patent lawyers to highlight the way a program controlled a physical machine made up of electrical circuits rather than the algorithm itself. Even after the emergence in the 1960s of general purpose computers that were designed to run a variety of programs, the key to getting a patent for operating code approved remained the same: focus on the physicality of the apparatus. In 1963, for example, IBM submitted a patent for automatic text recognition that was rejected. As Con Diaz shows, IBM then resubmitted the application, but changed the wording of the claims so that “a method of generating an unambiguous output in a system” became “an apparatus for generating an unambiguous outcome in a system.” The patent was approved.

One of the ironies of Con Diaz’s account was that throughout the 1960s and 1970s IBM was a vocal opponent of software patenting. What may at first glance seem incongruous makes sense once it is understood that IBM had negotiated a consent decree in an antitrust suit with the Justice Department in 1956 that compelled it to license its programs to almost anyone who asked, at a rate to be determined by the District Court for the Southern District of New York. IBM was not, therefore, seeking to earn licensing revenues. In fact, until 1969 IBM did not sell its software programs separately from its hardware: it bundled them together, leasing its hardware to businesses and then throwing in the software, training, and other services free of charge. The whole point of IBM’s strategy—aggressive patenting of its own programs, aggressive lobbying against software patenting, and the bundling of hardware and software—was to reduce the incentives of would-be competitors to enter the computer industry. The strategy worked extraordinarily well until 1969, when a new rival, Advanced Data Research (ADR), sued IBM for constraining the growth of the computer industry through its bundling practices. That same year, the Department of Justice initiated an antitrust suit against IBM. IBM responded by abandoning its bundling strategy, and the ADR suit was settled out of court. The antitrust action nonetheless ground on for thirteen years, until it was ultimately dropped by the government (Usselman 2009).

In what might be considered a double irony, ADR secured a patent in 1968 for a computer program called “Sorting System.” The literature has conventionally designated

"Sorting System" as the first software patent and has credited ADR with initiating an unprecedented expansion in the categories of inventions eligible for patent protection. As Con Diaz demonstrates, however, ADR's lawyers used precisely the same drafting strategy that IBM, Bell Labs, and other hardware manufacturers had pioneered to secure their patents for their programs. Given the prior success of this strategy, it was but a small step for the Patent Office to recognize that computer apparatuses are built out of programs in the same way that they are built out of patent-eligible components such as tape drives and transistors. ADR and other software development firms did not actually have to manufacture any hardware to invent something patentable; their software transformed a bunch of parts into a patent-eligible "special electrical circuit." The result was the emergence in the late twentieth century of one of America's most vibrant industries, and also of an entirely new group of producers to contend over the surplus generated by sales of computers.

Nirvana is Never on the Menu

Lawsuits over software patents have been important drivers both of the recent rise in patent litigation and of academic criticism of the patent system (Bessen and Meurer 2008; Allison, Lemley, and Walker 2009). Undoubtedly, there are useful ways to reform the process of obtaining software patents—for example, tightening up on continuing applications and on drafting standards for claims—that might reduce the number of lawsuits, just as limitations on reissues did in the late nineteenth century. But much of the recent rise in litigation is simply the inevitable result of the contest over surplus that arises with especial vehemence in new dynamic, competitive industries. Some critics have taken the imperfections of the patent system that we have highlighted in this essay—the politics, the lobbying, the litigation, the attempts to stretch the legal rules—as evidence that there must be a better way to promote inventive activity. But any critique of what actually exists necessarily implies a comparison: imperfect as compared to what? The statement that patents are a flawed and inefficient way of incentivizing innovation implies that there are other, more effective methods of encouraging technological development.

As B. Zorina Khan shows in "History Matters: National Innovation Systems and Innovation Policies in Nations," countries have experimented over the last several centuries with a number of different ways of encouraging inventive activity. Patent systems were not created out of whole cloth, but instead took form over time as nations tried out a variety of incentive systems in an environment characterized by intense international competition. The British patent system, for example, was not purposefully created to promote technological progress, but rather grew out of the early-seventeenth-century struggles between the King and Parliament that eventuated in the English Civil War. The primary purpose of the Statute of Monopolies that Parliament enacted in 1624 was to prevent the King from raising revenue by selling economically valuable privileges to wealthy supporters, but the act left open the possibility of granting temporary property rights to originators of inventions.[16] Over the next century or so, this possibility gradually took on the contours of a patent system—more through the gradual articulation of bureaucratic procedures by fee-seeking officials than through any legislative act or design. As a result, by the middle of the eighteenth century, inventors could secure patents for their inventions through a relatively standard—albeit cumbersome and expensive—process involving payments to multiple offices (Khan 2005; MacLeod 1988). During this same period, however, the British government was consciously and actively using more top-down methods to

[16] See Mossoff (2001) for a discussion of the intellectual history of emergence of patents as property rights in England, focusing in particular on the importance of natural-law conceptions of the social contract and the moral significance of labor.

promote the development of new technologies, particularly those of military importance (Khan 2015; Satia 2018).

One of the methods the government used during this period was to offer prizes for the solution of difficult technological problems. Technology prizes are much favored currently by critics of the patent system, and advocates have put forward a number of historical examples in support of their views (Stiglitz 2006; Brunt, Lerner, and Nicholas 2012; Burton and Nicholas 2017). The most famous example, the prize offered by Parliament in 1714 for a precise way of measuring longitude at sea, illustrates the main drawbacks of the method. In the first place, prizes must be awarded by human beings whose judgments may be clouded by prior beliefs about the way problems are most likely to be solved and about the kinds of people who are most likely to come up with solutions. The longitude problem was solved by John Harrison, a craftsman without formal education, who ran into both types of biases in his effort to collect his reward. Prominent members of the committee that Parliament created to administer the prize believed that the solution would be based on principles of celestial navigation, whereas Harrison instead produced a new type of clock capable of keeping time to an extraordinary degree of accuracy for long periods under adverse conditions. Harrison also faced skepticism because the committee, all of whose members came from the elite, expected the problem to be solved by a gentleman scientist of their own class. After decades of lobbying, including direct appeals to the King, Harrison was able in his old age to secure substantial remuneration from the British government, but the committee was never willing to declare he had won the prize (Sobel 1995; Khan 2015; Burton and Nicholas 2017).

The longitude example illustrates a second major problem with prizes. Harrison succeeded in making a clock with the necessary precision, but his chronometer was not commercially practicable. Indeed, chronometers remained so expensive that, despite the hazards of navigating without them, most ships continued to use less accurate celestial methods (Sobel 1995). What ultimately reduced the cost of the device sufficiently to spur mass adoption was the large number of follow-on inventions that materialized in the second half of the nineteenth century. In 1852 Parliament reformed the patent system so that it more resembled that of the United States. As the number of patents soared, so did patents for chronometers (Khan and Sokoloff 1997; Burton and Nicholas 2017).

Another drawback of prizes like the one for longitude is that the problems for which they invite solutions are well known. Many technological breakthroughs occur, however, when inventors discover solutions to problems that no one had ever thought to pose before. In order to encourage these kinds of unanticipated breakthroughs, both governments and private organizations have staged open competitions and fairs to reward outstanding developments in broad technological categories. Khan has studied a number of such competitions and found them to be infected by the same kinds of social and intellectual biases that confounded Harrison's attempts to secure the longitude prize. For example, the prizes awarded by Britain's Royal Society for the Encouragement of Arts, Manufactures, and Commerce during the century following its formation in 1754 went disproportionately to members of the elite. The practice was so blatant that contemporaries groused openly about it (see also Khan 2015). The case of the Royal Society is particularly telling because the organization prohibited prize winners from patenting their inventions. Khan found that inventors, including prominent members of the Society, voted with their feet and patented their most valuable inventions, submitting their less significant (or non-patentable) ideas to the competitions. In the end, the Society abandoned its system of prizes and devoted its resources instead to lobbying for reforms to strengthen the patent system.

Khan shows that other top-down methods of encouraging technological change, such as government buyouts of important inventions or direct efforts to promote specific types of technological change, were rife with similar problems and, on top of that, attracted hordes of rent seekers.[17] Governments have never definitively rejected these methods—perhaps because in some circumstances like war they have had useful outcomes—but over time they have gravitated toward patent systems through a trial-and-error process in which they learned from one another's successes and failures. The US patent system, for example, was a deliberate attempt to improve on the workings of the British patent system by simplifying the process of securing a patent and dramatically lowering the cost, so that every member of society could potentially contribute to technological progress. The Patent Act of 1793 put in place a registration system under which the Patent Office conducted only the most cursory checks for patentability, but mounting complaints by inventors seeking more certainty about the validity of their temporary property rights led to the creation of an examination system in 1836 (Khan 2005). After the American display at London's Crystal Palace exhibition in 1851 prompted worries about Britain's loss of technological leadership, the United Kingdom moved closer to the American model, lowering fees and simplifying the process of obtaining patents.[18] The US system also became the basis for Germany's patent law of 1877, as well as the Japanese patent law in 1888. The German patent

[17] Kremer (1998, 1138) credits the French government's buyout of Louis-Jacque-Mandé Daguerre's patent for photography with the rapid worldwide adoption and improvement of the technology, but the actual story is very different. Daguerre never obtained a French patent for the government to buy out, and the main inventor was actually his deceased business partner. With the patronage of an important member of the Académie des Sciences, he successfully lobbied the French government for a lifetime pension of 10,000 francs a year in exchange for making the technology available to the world. At the same time, however, he and a British patent agent were applying for a British patent for the same invention under the agent's name, and once they obtained the patent, the made a similar buyout offer (this time unsuccessfully) to the British government. See Khan (2015), pp. 637-38.

[18] Britain finally moved toward an examination system in stages in 1883 and 1902 (Khan 2008).

system, in turn, influenced the patent systems of Argentina, Austria, Brazil, Denmark, Finland, Holland, Norway, Poland, Russia and Sweden (Khan 2008).

Because patent systems are everywhere dominant, their imperfections are readily observable and open to criticism. But it is naïve to believe that any system devised by human beings to apportion economic surplus is going to be frictionless. For all their imperfections, US-style patent systems spread because they had multiple advantages. By creating property rights that could be traded in a market, they facilitated the development of a productive division of labor, either within the firm or through the market, that enabled inventors to specialize in technological discovery and leave the task of developing and commercializing their ideas to others. They also, as we have seen, made it possible for firms to transfer technological knowledge to other firms, even to firms in other countries. Moreover, patents are available not just to inventors of breakthrough technologies but as well to those who improve existing technologies incrementally or find novel ways to use them in other applications. This "democratization of invention" is a strength, not a weakness (Khan 2005). The vast majority of inventions have always had this follow-on character (Mokyr 1990). Precisely because the value of a patent does not inhere in the award itself but rather in the market value of the resulting property right, patent systems foster the kind of decentralized, cumulative improvement that extends the frontiers of what is economically possible. Moore's law takes a specific form in the case of computer chips, but the underlying principle is more general.

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