

WHAT DRIVES INNOVATION?

TOM NICHOLAS*

Antitrust policy should reflect changing viewpoints about the nature of innovation, but pinning down what drives innovation is not a simple task. Scholars at the intersection of law and economics have long grappled with the question, and so far only very broad generalizations appear possible. Primarily, we know that innovation contributes positively to the economy. In Joseph Schumpeter's words, it does so through creative destruction that "strikes not at the margins of the profits and outputs of existing firms but at their foundations and their very lives."¹ In endogenous growth models, economic progress depends on the production and diffusion of new ideas. According to this theory, innovation matters for just about everything.²

Establishing an optimal institutional framework for getting innovation incentives right is complex. Take patents as an example. Some theoretical work on intellectual property rights assumes a positive correlation between the strength of patent protection and the rate of innovation,³ but in the short run, patents also impose a deadweight loss arising from monopoly pricing. Intellectual property rights, while ostensibly established to provide inventors with incentives for pushing out the technology frontier, may be damaging to the process of innovation because they do not just confer rights over inventions, but also the rights over the price at which these inventions are sold.⁴ Moreover, since patents can be invalidated by the courts during infringement pro-

* Associate Professor of Business Administration, Harvard Business School. I thank Richard Rapp and Suzanne Scotchmer for very helpful comments and suggestions.

¹ JOSEPH A. SCHUMPETER, *CAPITALISM, SOCIALISM AND DEMOCRACY* 84 (1942).

² See generally Philippe Aghion & Peter Howitt, *A Model of Growth Through Creative Destruction*, 60 *ECONOMETRICA* 323 (1992); GENE M. GROSSMAN & ELHANAN HELPMAN, *INNOVATION AND GROWTH IN THE GLOBAL ECONOMY* (1991); Paul M. Romer, *Endogenous Technological Change*, 98 *J. POL. ECON.* 71 (1990).

³ Richard Gilbert & Carl Shapiro, *Optimal Patent Length and Breadth*, 21 *RAND J. ECON.* 106, 107 (1990).

⁴ MICHELE BOLDRIN & DAVID K. LEVINE, *AGAINST INTELLECTUAL MONOPOLY* 10 (2008).

ceedings, patents may be best thought of as probabilistic devices with a high degree of uncertainty over whether they will actually be enforced.⁵

The process by which new technology emerges is equally contentious. It has long been recognized that mechanisms like profits and capitalist institutions are needed for innovation to flourish. The returns that individual inventors and firms receive are determined by reward structures and these, in turn, are determined by government policy and by institutions. The reward structure can be modified to make productive pursuits more likely to occur, while depressing incentives for rent-seeking activities.⁶ Reward structures can influence both the demand side of innovation, by creating opportunities for profit, and the supply side of innovation, by determining the pool of potential innovators. Although supply is often neglected in favor of dominant frameworks that consider demand, recent research has elevated the role of supply as a crucial factor when accounting for the changing stock of new scientific and technological knowledge.⁷

Finally, financial markets play a central role in determining the pace of innovation. Financial intermediaries—such as banks, venture capitalists, private equity firms—redirect capital from where it is being saved to where it is needed. As Schumpeter argued, “risk obviously always falls on the owner of the means of production, or of the money-capital which was paid for them . . .”⁸ Financing innovation depends not only on an adequate supply of capital, it also requires efficient contracting to ensure entrepreneurs are productive and that financiers receive a return on their investment. The pace of innovation therefore depends on both the provision of capital and the mechanisms for establishing good governance.

In this article, I elaborate on three important factors that drive innovation: intellectual property institutions, the supply side of innovation, and the financing of technological development. While other factors—such as the nature of commercialization environments and market structure dynamics—are also important, the weighting on the three factors covered here should be large in any

⁵ Mark A. Lemley & Carl Shapiro, *Probabilistic Patents*, 19 J. ECON. PERSP. 75, 80 (Spring 2005).

⁶ WILLIAM J. BAUMOL, *ENTREPRENEURSHIP, MANAGEMENT, AND THE STRUCTURE OF PAYOFFS* 239 (1994).

⁷ See *infra* Part II.

⁸ JOSEPH A. SCHUMPETER, *THE THEORY OF ECONOMIC DEVELOPMENT: AN INQUIRY INTO PROFITS, CAPITAL, CREDIT, INTEREST, AND THE BUSINESS CYCLE* 75 (Redvers Opie trans., Transaction Publishers 1983) (reprint of 1934 ed.) (1911) [hereinafter *ECONOMIC DEVELOPMENT*].

explanation of what drives innovation.⁹ I conclude by assessing the implications of the research findings for antitrust policy.

I. INTELLECTUAL PROPERTY INSTITUTIONS

Few topics in the economics of technological change arouse as much controversy as the role of intellectual property. To the extent that consumer welfare is promoted through rapid technological progress, antitrust and intellectual property law share a common ground. There is much debate in the literature over the utility of patent systems for stimulating innovation, the downside to patents, and the deadweight losses that arise through monopoly pricing. Some authors argue that patent systems should be eliminated altogether because they impede rather than promote innovation. Others maintain that patents may be complemented by alternative mechanisms, such as inducement prizes that not only avoid deadweight losses but can lead inventors and firms to engage more optimally in the search for new ideas.

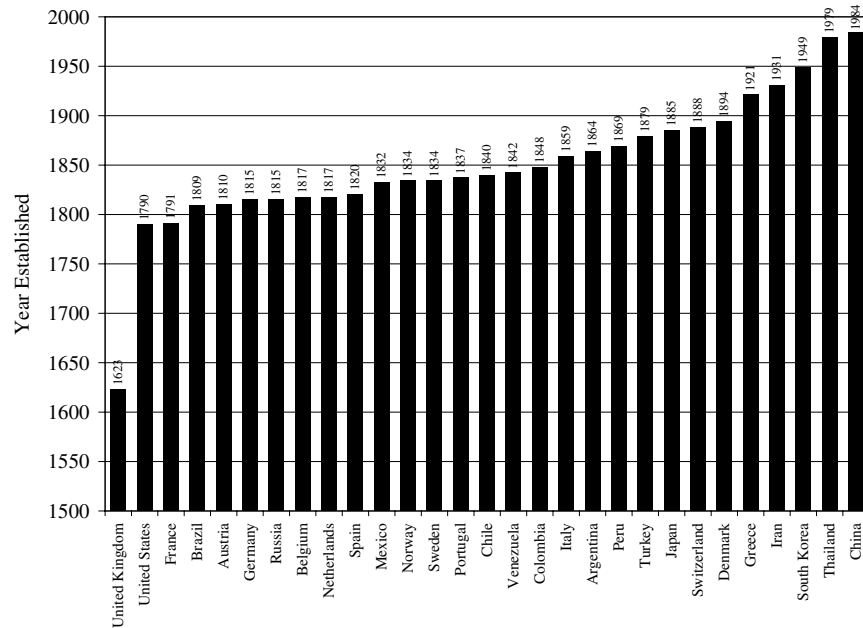
A. PATENTS AND COPYRIGHTS

Patents have been in place going back to at least 1474, when the Republic of Venice promulgated a decree stating that a new invention could be protected from imitation so long as it was useful, novel, and a working device. These criteria bear a striking resemblance to the ideas underpinning modern patent laws.¹⁰ Despite formal intellectual property rights diffusing across countries over time, some nations were relatively late in adopting patent protection. Figure 1 shows that 59 percent of the twenty-nine largest independent countries by gross domestic product at the end of the 20th century had patent systems in place by 1850. The latest adopters were Thailand, which enacted its first patent law in 1979, and China, which established patents in 1984. It is worth noting that the rapid rise of patent applications in China is in line with the country's extraordinary rate of economic growth. In 2009, a record number of 314,573 applications for patents on inventions were filed at the Chinese patent office, which compares to 457,966 utility patents filed in the United States the same year.

Although today all advanced industrial nations use patents, the utility of patents systems has repeatedly been called into question. Two prominent scholars of patent laws in the mid-20th century, Edith Penrose and Fritz

⁹ The literature on the drivers of innovation is vast, and it would be impossible to cover every contribution. The three main drivers discussed here have been chosen because they are prominent in recent research. Intellectual property institutions are commonly discussed in the context of antitrust policy. The other factors—the supply side and financing—cover complementary viewpoints about the mechanisms driving technological change.

¹⁰ In the United States, inventions must pass the three-pronged test of novelty, non-obviousness, and utility.



Source: Lerner, *150 Years of Patent Protection*, *infra* note 12.

FIGURE 1: YEAR PATENT SYSTEMS ESTABLISHED

Machlup, famously remarked on the ambivalence of these laws.¹¹ Given the preponderance of patent systems notwithstanding these critiques, it is important to understand why countries have them. Taking a long-run perspective, Josh Lerner analyzes how patent systems came about. He shows that wealthy democratic countries were more likely to have patent systems and that inventors generally were able to protect their inventions within well-defined legal systems. A country's legal origin helps to explain how intellectual property rights were defined, especially with respect to how foreign patentees are treated.¹² In a further contribution, Petra Moser shows that patent systems reflect a choice on the part of policymakers that has important implications for

¹¹ EDITH T. PENROSE, *THE ECONOMICS OF THE INTERNATIONAL PATENT SYSTEM* 40 (1951) ("If 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."); Fritz Machlup, *An Economic Review of the Patent System*, Study No. 15, Subcomm. on Patents, Trademarks, and Copyrights, Senate Judiciary Comm., 85th Cong., 2nd Sess. 80 (1958) ("If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it.")

¹² See generally Josh Lerner, *The Economics of Technology and Innovation: 150 Years of Patent Protection*, 92 *AM. ECON. REV.* 221 (2002) [hereinafter *150 Years of Patent Protection*].

the direction of technological change.¹³ When the Netherlands abandoned patent laws in 1869, for example, inventions exhibited at 19th century World's Fairs strongly shifted towards food processing, an area that could be protected by secrecy.¹⁴ These findings suggest that intellectual property rights have exerted a powerful influence over innovation historically. In today's global economy, the strength of patent protection can determine the extent to which multinational firms are willing to transfer knowledge to other countries. For instance, Lee Branstetter, Raymond Fisman, and C. Fritz Foley find international technology transfer is more likely to take place when patent laws are strengthened.¹⁵

Although patent systems can provide optimal incentives for technological development under certain conditions, one can argue that, in their traditional form, patents do not provide a first-best solution. Daron Acemoglu and Ufuk Akcigit consider an environment in which step-by-step innovation takes place and a technology gap exists between leaders and followers. Where technology advances in a series of steps, the original possessor of the intellectual property rights, the "leader," may control the development of each step and hence gain an increasing advantage over the "followers" without intellectual property rights—thereby adding to a "gap" in their ability to commercialize the technology. If patents establish proprietary knowledge that inhibits the research and development (R&D) of followers, the gap is bad for growth. But it is good for growth if leaders get rewarded with patents and they are further encouraged to push out the technology frontier. In a general equilibrium framework, the authors show that the largest distortions occur when governments remove intellectual property rights protection from leaders to close the technology gap with followers. Within this setup for examining the leader-follower dynamic, patents and competition policy can be aligned to promote innovation and enhance consumer welfare.¹⁶

One of the biggest controversies over how patent laws influence incentives for innovation concerns the effect of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs), which came into effect on January 1, 1995. Under TRIPs there is a strong push towards the harmonization of patent laws, which may exacerbate static distortions from monopoly pricing, espe-

¹³ See Petra Moser, *How Do Patent Laws Influence Innovation? Evidence from Nineteenth-Century World's Fairs*, 95 AM. ECON. REV. 1214 (2005).

¹⁴ *Id.* at 1229.

¹⁵ Lee G. Branstetter, Raymond Fisman & C. Fritz Foley, *Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from U.S. Firm-Level Panel Data*, 121 Q.J. ECON. 321, 322 (2006).

¹⁶ See Daron Acemoglu & Ufuk Akcigit, *State-Dependent Intellectual Property Rights Policy* (Nat'l Bureau of Econ. Res., Working Paper No. 12775, Dec. 2006), available at <http://www.nber.org/papers/w12775>.

cially in such areas as new drug development. Low-income countries were given until 2005 to amend their patent legislation and, using counterfactual simulations, Shubham Chaudhuri, Pinelopi Goldberg, and Panle Jia study the potential effects of the enforcement of product patents for pharmaceuticals in India.¹⁷ They confirm the hypothesis that product patents result in higher prices for essential medicines despite claims by global pharmaceuticals firms that therapeutic substitutes constitute an offset.¹⁸ The magnitude of the total welfare losses is large. They also produce a counterfactual simulation according to which firms receive only a small boost to profits under regulated prices.¹⁹ This finding questions whether TRIPS patenting applied to low-income countries provides sufficient incentives for firms to undertake additional investments in R&D.

One implication of these results is that alternative mechanisms to patents should be explored to provide innovation incentives. One alternative is compulsory licenses, which are granted by governments and allow a patented invention to be developed without the consent of the patent owner. In a well-documented case, the Brazilian government issued a compulsory license in 2007, which permitted the import of generic versions of efavirenz, used in the treatment of HIV infection, following a disagreement with patent-holder Merck & Co over pricing. Similarly, Thailand's Ministry of Health has used compulsory licenses for patents to produce antiretrovirals for HIV and clopidogrel, a heart medication sold by the biopharmaceutical giant Bristol Myers Squibb.

An important issue with examples like this is what happens to innovation in the long run as a consequence of these short-run changes in incentives. While such effects are difficult to observe for the modern era because the time horizons are too short, history can offer an answer. For example, by examining long-term adjustments following the Trading with the Enemy Act of 1917 (TWEA), Petra Moser and Alessandra Voena found that when German chemicals inventions were appropriated under the TWEA, the United States as a recipient country received large economic benefits.²⁰ Not only did TWEA allow U.S. inventors to exploit protected knowledge, but it encouraged long-run domestic innovation as firms built up new capabilities in the areas previously

¹⁷ See Shubham Chaudhuri, Pinelopi K. Goldberg & Panle Jia, *Estimating the Effects of Global Patent Protection in Pharmaceuticals: A Case Study of Quinolones in India*, 96 AM. ECON. REV. 1477 (2006).

¹⁸ *Id.* at 1481.

¹⁹ *Id.* at 1493–94.

²⁰ See Petra Moser & Alessandra Voena, *Compulsory Licensing: Evidence from the Trading with the Enemy Act* (Nat'l Bureau of Econ. Res., Working Paper No. 15598, Dec. 2009), available at <http://www.nber.org/papers/w15598>.

covered by foreign patents.²¹ An open question in this area is what happens to innovation in the country whose intellectual property rights have been appropriated. One concern is that gains in one country could be offset by losses elsewhere. From a political standpoint, retaliatory intellectual property rights measures are a possibility.

Notwithstanding that much of the literature on intellectual property rights has looked primarily at patents, alternative mechanisms like copyright have also been studied. One paper that gets to the heart of examining how non-patent intellectual property can affect innovation is Heidi Williams's study of the human genome.²² Human genome sequencing took place through the Human Genome Project (HGP), a public institution, and through Celera, a private firm, which sought to sequence the human genome independently. While HGP disclosed all of its results, Celera established a proprietary database to control the distribution of its knowledge through licensing arrangements. This situation held until HGP replicated and publicly disclosed Celera's results. Williams examines the effect of Celera's undisclosed intellectual property on subsequent innovation. The main finding is that the preservation of Celera's intellectual property had a strong negative impact on future R&D and product development.²³ Although the welfare effects are ambiguous—for one thing, the competition between HGP and Celera may have been welfare enhancing—Williams's analysis highlights the potentially damaging effects of intellectual property rights on follow-on innovation. That is, protecting intellectual property rights to upstream innovations can severely distort the path of cumulative technological progress.

B. PRIZES

Given the imperfections associated with intellectual property, a longstanding research stream has sought to establish the efficacy of other mechanisms, such as prizes. In an early contribution, Michael Polanyi suggested that prizes awarded by governments could work to encourage innovation and enhance consumer welfare because “[i]n order that inventions may be used freely by all, we must relieve inventors of the necessity of earning their rewards commercially and must grant them instead the right to be rewarded from the public purse.”²⁴

²¹ *Id.* at 21.

²² See Heidi L. Williams, *Intellectual Property Rights and Innovation: Evidence from the Human Genome* (Nat'l Bureau of Econ. Res., Working Paper No. 16213, July 2010), available at <http://www.nber.org/papers/w16213>.

²³ *Id.* at 2.

²⁴ Michael Polanyi, *Patent Reform*, 11 REV. ECON. STUD. 61, 65 (1944).

Inducement prizes can take different forms. Ex ante prizes offer awards to inventors prior to the invention taking place. A strict criterion for winning the prize is laid out and competitors are judged accordingly. This form of prize competition is typically used to spur invention in particular areas, especially those that create large welfare effects. Ex post prizes are used to reward the inventor after the breakthrough has taken place. For example, in a famous 1839 case often cited by economists, the French government purchased the Daguerreotype photography patent, establishing an annuity payment to the inventor, Louis Jacques Mande Daguerre, and his partner. After the patent was placed in the public domain, Daguerreotype photography rapidly diffused across the globe and the technology was cumulatively improved.²⁵

A further taxonomy of prize-based incentives is offered by Michael Kremer and Heidi Williams. They distinguish between “voluntary” and “mandatory” mechanisms, where the former supplement and the latter substitute for existing intellectual property regimes.²⁶ Voluntary mechanisms include those—like the Daguerreotype case—where patents are purchased by governments, allowing the knowledge to be freely exploitable in the public domain. Mandatory mechanisms include such programs as the Medical Innovation Prize Fund. Under this proposal, which was put before Congress in 2005, new drugs that receive FDA approval are immediately sold at generic prices, with innovators being compensated using a multi-billion dollar fund.²⁷

Recent interest in the use of prizes has been driven by the popularity of prize competitions, especially those run by the X-Prize Foundation, like the \$10 million prize for suborbital space flight it awarded in 2004.²⁸ Interestingly, the twenty-six teams that competed for the prize spent more than \$100 million to win it,²⁹ so entry was not primarily driven by the ability to recover the costs of research and development. NASA has sponsored prizes for technological innovation, most notably through its Centennial Challenges for innovative aerospace technologies, while other government-based initiatives are in the planning stages or have already been publicly announced.³⁰ In the pri-

²⁵ Michael Kremer, *Patent Buyouts: A Mechanism for Encouraging Innovation*, 113 Q.J. ECON. 1137, 1138 (1998).

²⁶ Michael Kremer & Heidi Williams, *Incentivizing Innovation: Adding to the Tool Kit*, in 10 INNOVATION POLICY AND THE ECONOMY 1, 10–11 (Josh Lerner & Scott Stern eds., 2010).

²⁷ *Id.* at 6.

²⁸ Thomas Kalil, *Prizes for Technological Innovation* 5–6 (Brookings Inst. Working Paper, Dec. 2006), available at <http://www.brookings.edu/views/papers/200612kalil.pdf>.

²⁹ *Ansari X-Prize*, X-PRIZE FOUNDATION, <http://space.xprize.org/ansari-x-prize>.

³⁰ Knowledge Ecology International, *Selected Innovation Prizes and Reward Programs* 13–15 (Research Note 2008:1) [hereinafter KEI], available at http://keionline.org/misc-docs/research_notes/kei_rn_2008_1.pdf.

vate sector, Prize Capital has proposed to use venture funds for contests to stimulate innovation in energy and environment-related areas.³¹

Interest in prizes is not new. Prizes were used extensively by governments, scientific societies, foundations, and private individuals throughout history. Table 1 shows instances of prizes offered in a number of countries in a range of areas, including medicine and transport.

TABLE 1: HISTORICAL EXAMPLES OF PRIZES

Year	Prize/Award	Offered by
1714	Longitude prize	British government
1795	Food preservation	Napoleon
1810	Sugar beet	Napoleon
1810	Flax spinning	Napoleon
1887	Medicine prizes	French Royal Academy of Sciences
1909	English Channel crossing	Daily Mail newspaper
1910	Fly across U.S. in under 30 days	William Randolph Hearst
1919	England-to-Australia air race	Australian Government
1800s & 1900s	Agricultural innovations	Royal Agricultural Society of England
1800s & 1900s	Technological Innovation	Local Governments, Japanese Prefectures

Source: *See* KEI, *supra* note 30 (all but the last two examples); Brunt, Lerner & Nicholas, *infra* note 39 (Royal Agricultural Society prizes); Nicholas, *infra* note 43 (Japanese prefecture prizes).

Napoleon Bonaparte was an advocate of prizes, as was the French Royal Academy of Sciences.³² The English newspaper *The Daily Mail* awarded £10,000 to John Alcock and Arthur Whitten Brown in 1919 for flying across the Atlantic inside seventy-two hours.³³ The Australian government offered the same amount for a flight between England and Australia.³⁴ William Randolph Hearst, the American newspaper magnate and publisher, offered \$50,000 for the first person to fly coast-to-coast across the United States in under thirty days, a prize that was never awarded.³⁵

Perhaps the most referenced prize in history is the 1714 prize offered by the British government for an instrument measuring longitude, an instance that highlights the advantages and disadvantages of rewarding inventors using prizes.³⁶ Because ships were being lost due to errors in gauging longitude, a

³¹ PRIZE CAPITAL, http://www.prizecapital.net/Prize_Capital/Home/Home.html.

³² KEI, *supra* note 30, at 6.

³³ *Id.* at 12.

³⁴ *Id.*

³⁵ *Id.*

³⁶ *See* DAVA SOBEL, *LONGITUDE: THE TRUE STORY OF A LONE GENIUS WHO SOLVED THE GREATEST SCIENTIFIC PROBLEM OF HIS TIME* 8 (1995).

substantial monetary prize was offered under a special Act of Parliament to encourage technological development.³⁷ John Harrison solved the navigational problem during the 1750s and ships were able to navigate more safely, but Harrison had to wait until 1773 for his prize to be partially paid following an acrimonious dispute over the conditions of the award.³⁸ Since this delay may have discouraged inventors from participating in future competitions, this case shows how the design of prize competitions—such as the transparency of rules and the timing of financial rewards—can influence their effectiveness.

Empirically, the study of prize competitions has been limited by the availability of data. To fill this gap, Liam Brunt, Josh Lerner, and I examine the effect of prizes on technological development using almost a century of data on *ex ante* prize competitions organized by the pre-eminent Royal Agricultural Society of England (RASE).³⁹ At annual shows the RASE used medals and monetary prizes to spur technological development. We find economically large effects of the prizes on contest entries and the quality of contemporaneous patents. Patents increased in technology categories of farm implements and machinery following the announcement by the RASE of prizes that were scheduled to be awarded in these categories.⁴⁰ Our econometric estimates rule out that the resulting patents were caused by contemporaneous demand or supply shocks to innovation.⁴¹ Furthermore, we note that non-pecuniary awards can be a particularly useful mechanism for inducing innovation, as inventors were motivated by the prospect of winning a medal.⁴²

I reported similar findings in a study of a hybrid innovation system of patents and prizes that operated in Japan during the late 19th and early 20th century.⁴³ Prize competitions were used to encourage competition and the diffusion of technological knowledge during the country's push towards economic modernization in the Meiji era. Between 1886 and 1911, there were 8503 competitive prize shows, with 9.9 million exhibits shown and 1.1 million prizes (mostly medals) awarded. Prizes significantly boosted patents in prefectures where a prize competition took place, and also inventors from adjacent prefectures benefited from spillovers of technological knowledge and

³⁷ *See id.*

³⁸ *See id.* at 8–9.

³⁹ Liam Brunt, Josh Lerner & Tom Nicholas, *Inducement Prizes and Innovation* (Harv. Bus. Sch. Working Paper No. 11-118, May 2011), available at <http://hbswk.hbs.edu/item/6724.html>.

⁴⁰ *Id.* at 5.

⁴¹ *Id.*

⁴² *Id.* at 4.

⁴³ Tom Nicholas, *Hybrid Innovation in Meiji Japan* (Harv. Bus. Sch. Working Paper, Jan. 2011), available at http://people.hbs.edu/tnicholas/Hybrid_Japan.pdf.

subsequently increased their patenting.⁴⁴ Notably, inventors could pursue patents and prizes simultaneously in Meiji Japan, just as they were able to under the RASE prize system. While much of the literature on prizes asserts that they can be used as a substitute for the patent system, the historical evidence shows that they complemented patents in providing incentives for inventors to invest in new technological discovery.

Theorists offer insights into prize program design, in an attempt to explain why prizes may offer advantages over patents. Kremer's government funded patent-buyout mechanism leads to an efficient level of innovation without deadweight loss. The patent buyout works by compensating the innovator for the loss of his monopoly rights when his invention is placed in the public domain. The value of the compensation is determined by an auction, which establishes the private value of the invention, and then a markup defined by a "typical" ratio of the social to the private value of the invention is added by the government to reflect the broader worth of the new technology to society. Because the mechanism allows the highest bidder to win in some of the auctions, bidders have incentives to bid truthfully. In doing so, the mechanism ensures that the innovator receives a reward that is commensurate with the cost of R&D and the social value that the innovation creates.⁴⁵ This approach goes a long way to addressing Brian Wright's concern that informational constraints limit the extent to which governments can determine the social value of an invention *ex ante*.⁴⁶

In a further contribution, Steven Shavell and Tanguy van Ypersele argue that giving the inventor an option to receive either a patent or a reward from the government can be optimal. If the government offers the lowest possible social surplus to the inventor, and he opts for a patent, the deadweight loss is the same as under patents. But if the inventor accepts the payment, then the deadweight loss is eliminated because the patent is forgone.⁴⁷ A difficulty with this mechanism is that the government needs information to be able to calculate the value of an award. Despite the solution offered by Kremer's patent-buyout mechanism, V.V. Chari, Mikhail Golosov, and Aleh Tsyvinski caution that if inventors can potentially distort market signals about value, then patents, rather than prizes, will be optimal.⁴⁸

⁴⁴ *Id.* at 15.

⁴⁵ Kremer, *supra* note 25, at 1137.

⁴⁶ Brian D. Wright, *The Economics of Invention Incentives: Patents, Prizes, and Research Contracts*, 73 AM. ECON. REV. 691, 691–92 (1983).

⁴⁷ Steven Shavell & Tanguy Van Ypersele, *Rewards Versus Intellectual Property Rights*, 44 J.L. & ECON. 525, 530 (2001).

⁴⁸ V.V. Chari, Mikhail Golosov & Aleh Tsyvinski, *Prizes and Patents: Using Market Signals to Provide Incentives for Innovations 3* (Fed. Res. Bank of Minneapolis, Working Paper No. 673, Aug. 2009), available at http://www.minneapolisfed.org/publications_papers/pub_display.cfm?id=4290.

II. THE SUPPLY SIDE

While the literature on intellectual property is concerned with how to encourage inventors and protect their new technological developments from imitation, a growing body of work has focused on examining the source of new ideas. Most of the literature on technological development adheres to the longstanding argument that the expectation of profit drives inventors to innovate, and this is an integral feature of modern economic growth models. New research, while not downplaying the role of the demand side, suggests that a closer look at the supply side is warranted because determining who actually innovates can inform our understanding of how new knowledge is developed and commercialized.

A. PRECURSOR: THE DEMAND-SIDE ARGUMENT

In any standard account of optimization and equilibrium, the objective function of firms is to maximize profits. Therefore, the speed of technological development should be strongly correlated with fluctuations in prospective demand. In a well-known historical study, Zvi Griliches found that the use of innovative hybrid maize seed varieties was determined by demand.⁴⁹ Iowa farmers active in the Corn Belt adopted hybrid corn faster than farmers in other agricultural regions, especially those active in the South, where the market potential was more limited.⁵⁰ Two other prominent scholars in the history of innovation, Jacob Schmookler and Kenneth Sokoloff, noticed that shifts in patents followed demand-side indicators, such as shifts in investment⁵¹ or the expansion of markets.⁵²

To illustrate how important demand-side factors can be today, consider that a major constraint on pharmaceutical innovation in areas like malaria prevention is the limit on expected profits that can be generated in low-income markets. Social returns to a malaria vaccine are estimated to be ten times larger than the private returns. Without the expectation of monetary gain, firms have few incentives to engage in costly R&D and many simply redirect their investment towards more profitable areas of drug development.⁵³ Even in advanced countries like the United States, market size exerts a powerful influence on the direction of R&D. This is revealed by Daron Acemoglu and Joshua Linn, who examine whether the entry and innovation in new pharma-

⁴⁹ See Zvi Griliches, *Hybrid Corn: An Exploration in the Economics of Technological Change*, 25 *ECONOMETRICA* 501 (1957).

⁵⁰ *Id.* at 522.

⁵¹ JACOB SCHMOOKLER, *INVENTION AND ECONOMIC GROWTH* 130–31 (1966).

⁵² Kenneth L. Sokoloff, *Inventive Activity in Early Industrial America: Evidence from Patent Records, 1790–1846*, 48 *J. ECON. HIST.* 813, 817 (1988).

⁵³ Michael Kremer, *Pharmaceuticals and the Developing World*, 16 *J. ECON. PERSP.*, Autumn 2002, at 67, 69 (2002).

ceutical products can be predicted by future shifts in U.S. demographics.⁵⁴ They establish that the total number of new drugs entering the U.S. market goes up by 4–6 percent for every 1 percent increase in potential market size, while the entry of new non-generic drugs goes up by 4 percent.⁵⁵ Their findings highlight that demand, by increasing expected profits, is a primary driver of innovation.

B. REVIVING THE SUPPLY SIDE

Yet, focusing exclusively on demand ignores the power of laws and economic environments to shape the supply of innovation. The supply of scientific and technical knowledge can be a central lever in pushing out the boundaries of what is technologically feasible. The scientific revolution of the 17th century created an auspicious environment for innovation, as did breakthroughs in science during the early 20th century in areas like polymer science, which paved the way for extensive chemical innovations several decades later.⁵⁶ In the modern era, Jeffrey Furman and Scott Stern show that institutions of science have had a powerful effect on fomenting innovation in the life sciences.⁵⁷

The impact of who actually does the innovating demonstrates why the supply side matters. Pierre Azoulay, Joshua Graff Zivin, and Jialan Wang examine what happens to the supply of knowledge when academic superstars die unexpectedly.⁵⁸ They show that the research productivity of their collaborators falls significantly relative to an otherwise equivalent control group.⁵⁹ This finding is economically important in its own right because it informs our understanding of how knowledge is produced in teams and networks, but it also has further implications, given that teams and networks depend on prominent superstars. The importance of this factor is highlighted in the work of Lynne Zucker, Michael Darby, and Marilyn Brewer, who show that the development of the U.S. biotechnology industry depended far more on the intangible knowledge assets of superstars than on the tangible physical assets of firms.⁶⁰

⁵⁴ Daron Acemoglu & Joshua Linn, *Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry*, 119 Q.J. ECON. 1049 (2004).

⁵⁵ *Id.* at 1051.

⁵⁶ JOEL MOKYR, *THE GIFTS OF ATHENA: HISTORICAL ORIGINS OF THE KNOWLEDGE ECONOMY* 109 (2002).

⁵⁷ See Jeffrey L. Furman & Scott Stern, *Climbing Atop the Shoulders of Giants: The Impact of Institutions on Cumulative Research*, 101 AM. ECON. REV. 1933 (2011).

⁵⁸ See Pierre Azoulay, Joshua S. Graff Zivin & Jialan Wang, *Superstar Extinction*, 125 Q.J. ECON. 549 (2010).

⁵⁹ See *id.* at 551.

⁶⁰ See Lynne G. Zucker, Michael R. Darby & Marilyn B. Brewer, *Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises*, 88 AM. ECON. REV. 290 (1998).

On a more general level, the innovators themselves have changed quite significantly over the last 100 years, as measured by the patent statistics shown in Figure 2. For instance, at the beginning of the 20th century, foreign inventors accounted for around 13 percent of all patents granted, and the share hovered around that level (with temporary drops during the two World Wars) until the early 1950s. By 1970, however, the share of patents granted to foreign inventors had doubled since the beginning of the century, a factor highlighted by Zvi Griliches in his landmark study of the patent statistics.⁶¹ Based on the data in Figure 2, in 2009, foreign inventors accounted for over half of all patents. Within this group, the majority of foreign patents were granted to Japanese (42 percent) and German (11 percent) inventors. Interestingly, the share of foreign-owned patents granted to Chinese inventors increased by a factor of almost fourteen between 2000 and 2009 (from 0.14 to 1.9 percent). Foreign ownership of domestically granted patents is a growing trend in the patent statistics and follows from such factors as the globalization of supply chains and the international spread of R&D.⁶²

The United States has always been a melting pot characterized by a multitude of immigrant cultures. Foreign-born persons account for around 10 percent of the U.S. working population, with the majority living in California, New York, Texas, and Florida. Contributions to innovation by foreign-born scientists and engineers could be large even within the series of patents granted to U.S.-domiciled inventors, as reflected in Figure 2. This raises at least two questions. First, how much of the supply side of innovation is driven by foreign-born inventors? Second, what mechanisms are in place to encourage, or inhibit, this form of technological development?

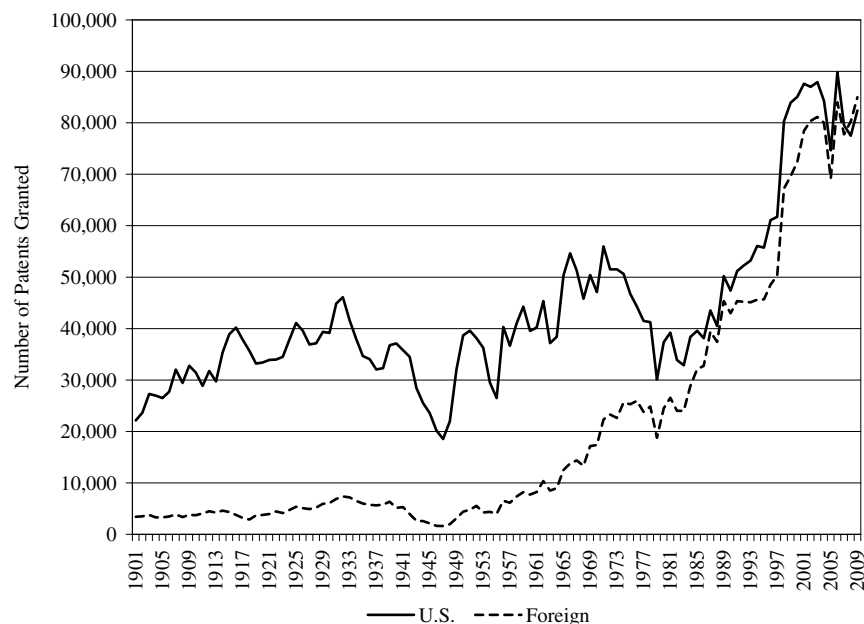
To address the first of these questions, William Kerr applies an ethnic-name database to U.S. patents.⁶³ The idea is to match surnames in patent documents like “Chang” or “Wang” with Chinese ethnicity and surnames like “Rodriguez” or “Martinez” with Hispanic descent. This approach, while subject to measurement error because it cannot separate out foreign-born inventors working in the United States from first or later generations of inventors, suggests that there is a growing concentration of what Kerr describes as “ethnic inventors” in the innovation community.⁶⁴ While Kerr’s English, or Anglo-Saxon, ethnicity (which would encompass inventors with such surnames as

⁶¹ Zvi Griliches, *Patent Statistics as Economic Indicators: A Survey*, 28 J. ECON. LIT. 1661, 1664 (1990).

⁶² See Pol Antras, *Property Rights and the International Organization of Production*, 95 AM. ECON. REV. 25 (2005); Pol Antras & Elhanan Helpman, *Global Sourcing*, 112 J. POL. ECON. 552 (2004).

⁶³ William R. Kerr, *The Ethnic Composition of US Inventors* (Harv. Bus. Sch. Working Paper No. 08-006, Dec. 2008), available at <http://www.hbs.edu/research/pdf/08-006.pdf>.

⁶⁴ *Id.* at 1–2.



Source: U.S. Pat. & Trademark Off., Extended Year Set—Patents by Country, State, and Year: Utility Patents (Dec. 2010), http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utlh.htm (1963–2009 data); WORLD INTELLECTUAL PROPERTY ORGANIZATION, 100 YEARS OF INDUSTRIAL PROPERTY STATISTICS 97 tbl.1 (1983) (1901–1963 data).

FIGURE 2: U.S. PATENTS GRANTED TO U.S. AND FOREIGN INVENTORS

Adams, Edwards, or Jones) share of total patents granted between 1975 and 2004 fell from 83 percent to 70 percent and his European ethnicity (which would encompass inventors with such surnames as Albrecht, Ehrlich, or Jacobs) share fell from 8 percent to 6 percent, patents by inventors with other ethnicities increased.⁶⁵ In particular, patents by ostensibly Chinese and Indian inventors increased substantially during the 1990s,⁶⁶ at a time when the United States was undergoing a technological revolution in the development and implementation of information and communications technologies.⁶⁷ The concentration of these inventors in high-tech sectors and their agglomeration in cities, which act as hubs of innovation, indicate that “ethnic inventors” are an important factor when explaining the supply side of technological develop-

⁶⁵ *Id.* at 7.

⁶⁶ *Id.* at 2.

⁶⁷ See generally Lubos Pastor & Pietro Veronesi, *Technological Revolutions and Stock Prices*, 99 AM. ECON. REV. 1451 (2009).

ment.⁶⁸ Furthermore, Paula Stephan and Sharon Levin, who observe birth and educational origin directly in databases listing foreign-born individuals working in the United States, show that those born and educated abroad have made larger contributions to science and engineering than their share of the population would suggest.⁶⁹

The second question—what mechanisms encourage or discourage foreign-born contributors to innovation—is the topic of papers by Jennifer Hunt and Marjolaine Gauthier-Loiselle, and William Kerr and William Lincoln. Their studies pertain to the contentious debate surrounding the optimal number of employer-sponsored H-1B visas available for skilled workers who could be employed in patent-related areas. Hunt and Gauthier-Loiselle find a positive correlation between the share of immigrants holding degrees and patenting outcomes, and find that this spur to innovation does not reflect the “crowding-out” or displacement of domestic inventors.⁷⁰ Additionally, they show the immigrant talent pool creates spillovers and thus contributes both directly and indirectly to the process of innovation.⁷¹ Kerr and Lincoln also test for crowding-out and spillover effects by examining changes in the ethnic composition of inventors following changes in H-1B quotas.⁷² They find that when the national population of H-1B visa-holders increases, patenting by inventors with Indian and Chinese surnames also rises.⁷³ According to Kerr and Lincoln, this evidence suggests that the level of invention was higher as a consequence of the contributions made by immigrants.⁷⁴

III. FINANCING INNOVATION

The functioning of capital markets has an obvious bearing on the level and speed of innovation and hence the rate of economic growth. The point was obvious to Joseph Schumpeter, who wrote about the centrality of financing to innovation,⁷⁵ and to Merton Miller, who argued that the positive effect of ready financing “is a proposition almost too obvious for serious discussion.”⁷⁶

⁶⁸ See William R. Kerr, *The Agglomeration of U.S. Ethnic Inventors*, in *AGGLOMERATION ECONOMICS* 237 (Edward Glaeser ed., 2010).

⁶⁹ Paula Stephan & Sharon Levin, *Foreign Scholars in U.S. Science: Contributions and Costs*, in *SCIENCE AND THE UNIVERSITY* 237 (Ronald Ehrenberg & Paula Stephan eds., 2010).

⁷⁰ Jennifer Hunt & Marjolaine Gauthier-Loiselle, *How Much Does Immigration Boost Innovation?*, 2 *AM. ECON. J.: MACROECONOMICS* 31, 33 (2010).

⁷¹ *Id.*

⁷² William R. Kerr & William F. Lincoln, *The Supply Side of Innovation: H-1B Visa Reforms and U.S. Ethnic Invention*, 28 *J. LABOR ECON.* 473 (2010).

⁷³ *Id.* at 490.

⁷⁴ *Id.* at 504.

⁷⁵ See SCHUMPETER, *ECONOMIC DEVELOPMENT*, *supra* note 8, at 75.

⁷⁶ Merton H. Miller, *Financial Markets and Economic Growth*, 11 *J. APPLIED CORP. FIN.* 8, 14 (1998).

But despite the consensus that finance is an important variable, considerable research has nonetheless been devoted to determining if, and precisely how, finance drives innovation.⁷⁷

A. FACTS AND FINDINGS

If technological progress is driven by finance, it would be natural to find lower rates of innovation, other things being equal, in places where financial constraints dominate. Cross-country growth regressions with indicators for financial development reveal a positive correlation between higher levels of financial development and faster rates of economic growth.⁷⁸ It remains unclear, however, whether finance drives growth or vice versa. Using a broad set of countries in transition, mostly in Eastern Europe, Yuriy Gorodnichenko and Monika Schnitzer attempt to identify a causal path by showing that domestically owned firms in these countries are less productive and less innovative than foreign-owned firms, which the authors attribute to differences in the ability to access capital.⁷⁹ This financial frictions explanation provides one way to explain why transition economies face such difficulties in catching up to technological leaders.⁸⁰

By implication, countries with more efficient capital markets should be able to devote more resources to innovation. Statistics show that the United States is the global leader in terms of aggregate R&D investment. In purchasing-parity terms, the OECD estimates that in 2007 gross domestic expenditure on R&D was two-and-a-half times larger in the United States than in the next most prominent country—Japan.⁸¹ When considering the ratio of R&D to GDP, the United States falls behind Japan, but R&D still accounted for about 2.7 percent of GDP in 2007⁸² and was never less than 2.5 percent of GDP in any year going back to 1995.⁸³ Based on National Science Foundation data, Figure 3 shows the large scale of financing needs. Real, privately funded and financed R&D expenditure in the United States rose by a factor of almost eighteen between 1953 and 2008 (from \$12 billion to \$215 billion), with

⁷⁷ See Ross Levine, *Financial Development and Economic Growth: Views and Agenda*, 35 J. ECON. LIT. 688 (1997) (collecting authorities).

⁷⁸ See Robert G. King & Ross Levine, *Finance and Growth: Schumpeter Might Be Right*, 108 Q.J. ECON. 717, 719 (1993).

⁷⁹ Yuriy Gorodnichenko & Monika Schnitzer, *Financial Constraints and Innovation: Why Poor Countries Don't Catch Up* 2 (Nat'l Bureau of Econ. Res., Working Paper No. 15792, Mar. 2010), available at <http://www.nber.org/papers/w15792>.

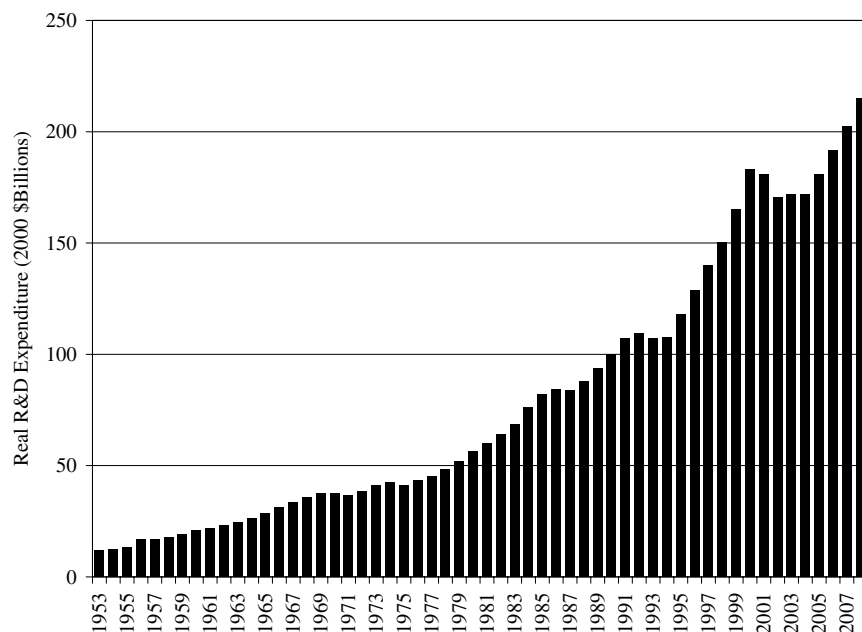
⁸⁰ *Id.*

⁸¹ OECD (2010), Main Science and Technology Indicators, OECD Science, Technology and R&D Statistics (database).doi: 10.1787/data-00182-en.

⁸² *Id.*

⁸³ OECD (2009), Main Science and Technology Indicators, OECD Science, Technology and R&D Statistics (database).doi: 10.1787/msti-v2009-1-table2-en-fr.

probably around one-half of that amount going to remuneration for research workers. The series reaches a local peak in 2000, coincident with the high-point of market valuations on Nasdaq. Although expenditure fell off in 2002, by 2008 it was about 18 percent higher than it had been in 2000. R&D expenditure appears to have been quite resilient to the effects of the 2008 financial crisis.



Source: Nat'l Sci. Found., Division of Science Resources Statistic, National Patterns of R&D Resources: 2008 Data Update, tbl.1 (NSF 10-314, 2010) (privately funded and financed R&D), available at http://www.nsf.gov/statistics/nsf10314/content.cfm?pub_id=4000&id=2.

FIGURE 3: REAL R&D EXPENDITURES IN THE UNITED STATES, 1953–2008

An important fact about R&D is its movement relative to the business cycle. Gadi Barlevy shows that in U.S. manufacturing over the period 1958–2003, R&D tended to be procyclical.⁸⁴ Barlevy notes that one explanation for the procyclicality of R&D is that, if knowledge is appropriable by others, the desire to maximize returns leads firms to concentrate R&D activity during booms and deters them from undertaking R&D in recessions.⁸⁵ Since,

⁸⁴ Gadi Barlevy, *On the Cyclicity of Research and Development*, 97 AM. ECON. REV. 1131, 1133–34 (2007).

⁸⁵ *Id.* at 1139–40.

by this mechanism, firms are in effect paying more for R&D than they would otherwise need to do—because resource costs are higher in booms than in recessions—the pro-cyclical nature of R&D provides a rationale for fiscal incentives like tax credits to spur research investment during downturns.⁸⁶ An alternative explanation for the procyclicality of R&D is that it is caused by financing constraints.⁸⁷ Firms would prefer to exploit lower resource costs in recessions but instead they wait until booms for financing conditions to improve.⁸⁸

Financial constraints are notoriously difficult to identify empirically.⁸⁹ The usual method for estimating their size and significance is to test for liquidity effects in R&D investment specifications. Because most R&D is financed by firms internally, the presence of financial constraints should show up in excess sensitivity of research investment to cash flow shocks. The problem with this approach is that cash flow shocks of a big enough magnitude are rarely observable. Additionally, there may be large composition effects whereby not all firms are affected equally by financing. Established firms with deeper pockets may react differently to financing channels relative to startups.

This last point is particularly relevant in a study of R&D investment during the 1990s technology boom by James Brown, Steven Fazzari and Bruce Petersen.⁹⁰ They show that in high-tech sectors that have a large weighting in overall R&D investment (i.e., drugs, office and computing equipment, communications equipment, electronic components, scientific instruments, medical instruments, and software), young firms relied on cash flow and issuing public equity far more than older firms.⁹¹ Importantly for the hypothesis of the finance-growth nexus, they find that the magnitude of the finance-induced effects for younger firms is large enough to explain about three quarters of aggregate movements in R&D between 2001 and 2004.⁹² Also of note is the finding that equity markets had a strong impact on financing relative to banks, implying a major shift in the origins of investment capital.⁹³

⁸⁶ *Id.* at 1132.

⁸⁷ *Id.* at 1139.

⁸⁸ Philippe Aghion, George-Marios Angeletos, Abhijit Banerjee & Kalina Manova, *Volatility and Growth: Credit Constraints and the Composition of Investment*, 57 J. MONETARY ECON. 246, 246–47 (2010).

⁸⁹ See Bronwyn H. Hall & Josh Lerner, *The Financing of R&D and Innovation* 16–17 (Nat'l Bureau of Econ. Res., Working Paper No. 15325, Sept. 2009), available at <http://www.nber.org/papers/w15325.pdf>.

⁹⁰ See James R. Brown, Steven M. Fazzari & Bruce C. Petersen, *Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom*, 64 J. FIN. 151 (2009).

⁹¹ *Id.* at 152.

⁹² *Id.* at 171.

⁹³ *Id.* at 153.

B. VENTURE CAPITAL AND PRIVATE EQUITY

Two particularly fertile areas in the literature are the role of venture capital and private equity in financing innovation over the life cycle of firms. The rate of return on an investment required by an entrepreneur, or firm, can often be much lower than the cost of capital, while problems of asymmetric information lead potential investors to be overly cautious in funding innovation projects that require external rather than internal funds because of the “lemons problem,” or bad-project risk. Probably the most significant shift in the financing of innovation in the modern era in response to this funding gap is the rise of venture capital. In the first quarter of 2010, venture capitalists invested \$4.7 billion in U.S. companies.⁹⁴

Since both venture capital firms and innovation-based startups are located in places like Silicon Valley, an important question is the extent to which access to investment capital is a primary driver of innovation, or whether these geographic locations are innovative for other less obvious reasons. Samuel Kortum and Josh Lerner address this issue and find a strongly positive and economically important relationship between finance and innovation.⁹⁵ Specifically, they argue that the presence of venture capital between 1965 and 1992 can account for around 8 percent of industrial innovations as measured by patenting, a disproportionately large share given that venture funds accounted for approximately 3 percent of R&D expenditure during the same time period.⁹⁶

Others have attempted to uncover the factors that might help to explain the boost that venture capital provides. Among other things, Thomas Hellmann and Manju Puri⁹⁷ show that venture capital investors are quick to replace the founding team with outside managers—a good governance mechanism that has deep roots in the literature going back to the historical writings of Alfred D. Chandler on the optimal organization of firms⁹⁸ and in more recent work by Nicholas Bloom and John Van Reenen on the importance of efficient management practices.⁹⁹ Steven Kaplan and Per Stromberg show that venture capitalists provide effective due diligence, monitoring, and financial contracting

⁹⁴ DOW JONES VENTURESOURCE (Apr. 17, 2010), http://www.dowjones.com/pressroom/SM_PRs/PM/1Q10USFinancing.html.

⁹⁵ See Samuel Kortum & Josh Lerner, *Assessing the Contribution of Venture Capital to Innovation*, 31 RAND J. ECON. 674 (2000).

⁹⁶ *Id.* at 674, 691.

⁹⁷ See Thomas Hellmann & Manju Puri, *Venture Capital and the Professionalization of Start-Up Firms: Empirical Evidence*, 57 J. FIN. 69 (2002).

⁹⁸ ALFRED D. CHANDLER, JR., *THE VISIBLE HAND: THE MANAGERIAL REVOLUTION IN AMERICAN BUSINESS* 484–500 (1977).

⁹⁹ Nicholas Bloom & John Van Reenen, *Measuring and Explaining Management Practices Across Firms and Countries*, 122 Q.J. ECON. 1351 (2007).

arrangements.¹⁰⁰ Josh Lerner shows that these advantages are difficult to replicate, as evidenced by the limited success of government-induced entrepreneurship initiatives across the globe.¹⁰¹

In a world where venture-backed startups introduce technology that leads to the displacement of incumbents, venture capital can be seen as a major spur to creative destruction. The role of private equity leverage buyouts (LBO), on the other hand, is the subject of much controversy. Proponents of the LBO model, whereby acquisition debt is raised on a target company, suggest that efficiencies should create incentives for long-term investments.¹⁰² On the other hand, because private equity funds face short-term pressures to exit from firms profitably, long-term investment in innovation may be forgone. To provide insight into the effect of LBOs on innovation, Josh Lerner, Morten Sorensen, and Per Stromberg examine the patenting behavior of firms subjected to LBOs during a period that includes the major restructuring wave of the 1980s and 1990s. They find that patent citations, as a measure of patent quality, increased significantly after the LBO event relative to before it. Although they do not fully establish causality—one potential source of bias is that latently innovative firms are selected into private equity deals—their evidence does suggest that concerns over the role of private equity stifling innovation are misplaced.¹⁰³

IV. CONCLUSION

Innovation is driven endogenously by a complex set of factors, including the three broad areas of influence considered in this survey: intellectual property rights, the supply side of innovation, and the financing of technological development. Notwithstanding the breadth and complexity of the material, some summary conclusions and implications for antitrust policy are possible.

First, with respect to intellectual property rights, while some authors argue that patents should be abandoned altogether, as Richard Gilbert points out, “a world without intellectual property is an interesting subject for speculation . . . [b]ut it is not a world we are likely to see.”¹⁰⁴ The more likely scenario is that

¹⁰⁰ See generally Steven N. Kaplan & Per Stromberg, *Financial Contracting Theory Meets the Real World: An Empirical Analysis of Venture Capital Contracts*, 70 *REV. ECON. STUD.* 281 (2003); Steven N. Kaplan & Per Stromberg, *Characteristics, Contracts, and Actions: Evidence from Venture Capitalist Analyses*, 59 *J. FIN.* 2177 (2004).

¹⁰¹ JOSH LERNER, *BOULEVARD OF BROKEN DREAMS: WHY PUBLIC EFFORTS TO BOOST ENTREPRENEURSHIP AND VENTURE CAPITAL HAVE FAILED—AND WHAT TO DO ABOUT IT* 7 (2009).

¹⁰² Michael C. Jensen, *Eclipse of the Public Corporation*, 67 *HARV. BUS. REV.* 61, 69–70 (2002).

¹⁰³ Josh Lerner, Morten Sorensen & Per Stromberg, *Private Equity and Long-Run Investment: The Case of Innovation*, 2 *J. FIN.* 445, 474 (2011).

¹⁰⁴ Richard Gilbert, *A World Without Intellectual Property? A Review of Michele Boldrin and David Levine's Against Intellectual Monopoly*, 49 *J. ECON. LIT.* 421, 431 (2011).

lawmakers will opt for hybrid solutions—that is, complementing patents with alternative mechanisms, such as prizes, in sectors where social value is high, like new drug discovery or environmental technologies, while maintaining patents in sectors where private returns dominate. Antitrust policy has typically involved an uncomfortable tradeoff between granting monopoly rights and tolerating deadweight losses through patents to foster incentives for innovation. Policymakers may find that, under certain conditions, positive incentives can be maintained without deadweight losses using prize-based mechanisms. This may portend a significant change in the relationship between antitrust and intellectual property.

Second, research into the supply side of innovation identifies how changes in the supply of human capital can have an economically important impact on how, and why, technological development takes place. Antitrust characteristically addresses market power abuses designed to act as barriers to the supply of new products. Yet, where the speed of knowledge creation increases, the subsequent threat of substitute inventions, or major technological discontinuities, may naturally negate incumbent advantages. If scientific progress accelerates because of supply-side advances, the demand for antitrust enforcement may weaken, specifically because the commercialization of new ideas generates rapidly innovating and dynamic industries.

Third, the strong mediating link between capital, invention, and economic progress has arguably strengthened in recent years (despite the shock of the 2008 financial crisis). Inasmuch as financial needs have changed over time in response to movements in the scale of industry, the way in which capital is supplied—e.g., the institutionalization of venture capital and private equity—has also shaped the capacity of economies to develop and absorb new technologies. Efficient capital markets may lead to the consolidation of market power through mergers and acquisitions and overlapping ownership, which come under the purview of antitrust scrutiny. But developments in capital markets can also allay antitrust concerns because they provide a catalyst to entrepreneurial entry, leading to greater competition and an increase in the overall rate of technical advancement through creative destruction.

Taken together, the research surveyed here implies a changing economic environment for innovation, which should be reflected in policy to promote competition and enhance consumer welfare. Views about what drives innovation shape our thinking about how markets work and how firms respond to incentives, and they should also be an integral feature of antitrust debate. That does not mean that the lessons from new research are simple or straightforward. In fact, most scholars at the intersection of law and economics would answer the question, “What drives innovation?” with an unambiguous, “We

do not know.” Yet, where robust results do emerge in relation to factors that we know strongly impact technological change, findings from the literature on the economics of innovation should provide a good starting point.

