

SCIENTIFIC ENTREPRENEURSHIP: THE STEALTH CONDUIT OF UNIVERSITY KNOWLEDGE SPILLOVERS

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INTRODUCTION

The development and implementation of policy instruments to spur American innovative activity have emerged as a priority for U.S. public policy. For example, in a February 2011 white paper entitled “A Strategy for American Innovation: Securing Our Economic Growth and Prosperity,” President Obama emphasized the key role of public policy to facilitate and generate innovative activity, stating,

America’s future economic growth and international competitiveness depend on our capacity to innovate. We can create the jobs and industries of the future by doing what America does best—investing in the creativity and imagination of our people. To win the future, we must out-innovate, out-educate, and out-build the rest of the world.¹

In his 2011 State of the Union Address to the U.S. Congress, President Obama reiterated that, “We have to make America the best place on earth to do business.”²

This is not the first time that public policy in the United States has turned to innovative activity to serve as an engine of economic growth, job creation, and competitiveness in internationally linked markets. In response to the economic stagnation of the late-1970s, Congress in 1982 enacted the Small Business Innovation Research (“SBIR”) program with an explicit goal of reinvigorating jobs and growth by enhancing the innovative performance of the United States. In particular, Congress’s explicit mandate was created to spur innovative activity and technological change.³ However, Congress deemed the passage of the SBIR insufficient. In addition, the pas-

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¹ THE WHITE HOUSE, NAT’L ECON. COUNCIL, COUNCIL OF ECON. ADVISERS, & OFFICE OF SCI. & TECH. POLICY, A STRATEGY FOR AMERICAN INNOVATION: SECURING OUR ECONOMIC GROWTH AND PROSPERITY 1 (2011), available at <http://www.whitehouse.gov/sites/default/files/uploads/InnovationStrategy.pdf>.

² Brian Wingfield, *Obama’s Innovation Agenda*, FORBES (Jan. 25, 2011, 9:50 PM), <http://www.forbes.com/sites/brianwingfield/2011/01/25/obamas-innovation-agenda/>.

³ *Spurring Innovation and Job Creation: The SBIR Program: Hearing Before the H. Comm. On Small Bus.*, 112th Cong. 1 (2011) (testimony of David B. Audretsch, Professor, Indiana Univ.), available at http://smallbusiness.house.gov/uploadedfiles/david_audretsch_sbir_testimony.pdf.

sage of the Bayh-Dole Act in 1980 particularly targeted the role of the universities.⁴ The Bayh-Dole Act created an explicit mandate to facilitate knowledge spillovers from university research.

Studies providing an evaluation of the impact of the Bayh-Dole Act generally have produced mixed results, causing a somewhat ambiguous assessment of the Act. On the one hand, patent activity registered by universities has increased dramatically.⁵ For example, between 2000 and 2008 U.S. universities filed 83,988 new patent applications.⁶ At the same time, universities signed 41,598 new license and option agreements.⁷

On the other hand, studies have provided compelling evidence that only a handful of universities have actually generated large flows of licensing revenue. Most universities have generated only a paucity of revenue accruing from licensed technologies. Similar research has found that the number of start-ups spawned by universities has been modest at best, leading many to conclude that the Bayh-Dole Act has not succeeded in enabling the universities to effectively transfer technology and spur knowledge spillovers from their research. “Bayh-Dole critics postulate that universities and technology transfer offices are inefficient obstacles to the formation of startup companies.”⁸

The purpose of this Article is to suggest that this rather negative assessment of university technology transfer and knowledge spillovers in general—and scientist entrepreneurship in particular—as inefficient is skewed and does not accurately reflect the reality at universities in terms of the commercialization of scientific research and new knowledge. This Article explains why the development of new sources of data which do not rely on information gathered by technology transfer offices and made publicly available by the Association of University Technology Managers (“AUTM”), suggests a considerably more robust view of the evolving role of the university in contributing to innovation and economic growth.

⁴ E.g., Bayh-Dole Act, Pub. L. 96-517, § 202, 94 Stat. 3015, 3020-22 (1980) (codified as amended at 35 U.S.C. § 202 (2012)).

⁵ David C. Mowery, *The Bayh-Dole Act and High-Technology Entrepreneurship in U.S. Universities: Chicken, Egg, or Something Else?*, in 16 *ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION, AND ECONOMIC GROWTH: UNIVERSITY ENTREPRENEURSHIP AND TECHNOLOGY TRANSFERS: PROCESS, DESIGN, AND INTELLECTUAL PROPERTY* 39, 52-53 (Gary D. Libecap ed., 2005) [hereinafter Mowery, *Chicken, Egg, or Something Else?*]; DAVID C. MOWERY ET AL., *IVORY TOWER AND INDUSTRIAL INNOVATION: UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER BEFORE AND AFTER THE BAYH-DOLE ACT IN THE UNITED STATES* 134-44 (Martin Kenny & Bruce Kogut eds., 2004) [hereinafter MOWERY ET AL., *IVORY TOWER*].

⁶ Phillip H. Phan & Donald S. Siegel, *The Effectiveness of University Technology Transfer*, 2 *FOUND. & TRENDS IN ENTREPRENEURSHIP* 77, 80-81 (2006).

⁷ *Id.*

⁸ Arundeeep S. Pradhan, Viewpoint, *Defending the University Tech Transfer System*, BLOOMBERGBUSINESSWEEK (Feb. 19, 2010), http://www.businessweek.com/smallbiz/content/feb2010/sb20100219_307735.htm.

Part I of this Article explains the way in which the university has evolved from the Humboldt model of the university toward a model that facilitates both the creation and commercialization of new scientific knowledge. Part II explains why new knowledge created at universities does not automatically spill over for commercialization and innovation. Part III analyzes the relatively unexplored role of university scientist entrepreneurship. Finally, a summary and conclusions are provided. Analyzing the commercialization activities of individual scientists rather than those reported by offices of technology transfer leads to a considerably more positive assessment of not just the Bayh-Dole Act's impact but, more importantly, American universities' contributions to innovative activity.

I. THE EVOLVING ROLE OF THE UNIVERSITY

The role of the university during the post-World War II era was largely shaped by and restricted to the model Wilhelm von Humboldt created.⁹ Wilhelm von Humboldt was a giant among scholars and statesmen in Berlin, who liberated the university from the dictates of society, and in particular from the control of governments and the church. Prior to Humboldt, the church and the government dictated what and how research and teaching were undertaken. Von Humboldt freed scholars to pursue knowledge for its own sake and not because it met the approval or needs of any outside source. The universities cherished this marked division or wall because it protected professors from external intervention and influence as to what and how research and teaching should be undertaken.

The Humboldt model of the university, which was essentially separate from society and contributed little in the way of knowledge spillovers or contribution to economic growth, was certainly consistent with the prevailing model of economic growth that prevailed in the decades following the Second World War. As the Nobel Prize laureate Robert Solow made brilliantly clear, what mattered for economic growth came down to two distinct factors—physical capital (meaning machines, plants, and factories) and labor (that is, people to work in those factories in assembly lines).¹⁰ In fact, Solow's empirical model was unable to explain most economic growth, which remained unexplained in the residual. Solow interpreted the unexplained residual as representing the unobserved factors of technical change. Professor Richard Nelson subsequently pointed to the emergence of a large body of literature providing empirical estimates of the Solow model. In this literature, while the actual context varied according to the country and time

⁹ See generally DAVID B. AUDRETSCH, *THE ENTREPRENEURIAL SOCIETY* 144-46, 149 (2007); HAROLD T. SHAPIRO, *A LARGER SENSE OF PURPOSE: HIGHER EDUCATION AND SOCIETY* 73-77 (2005).

¹⁰ See Robert M. Solow, *A Contribution to the Theory of Economic Growth*, 70 Q.J. ECON. 65, 65-66, 68 (1956).

period, economic growth was invariably linked to the two main factors of physical capital and labor:

Since the mid-1950s, considerable research has proceeded closely guided by the neoclassical formulation. Some of this work has been theoretical. Various forms of the production function have been invented. Models have been developed which assume that technological advance must be embodied in new capital. . . .

Much of the work has been empirical and guided by the growth accounting framework implicit in the neoclassical model.¹¹

There seemed to be little that the universities, which essentially produce ideas, could contribute in an economy where factories and machines were the driving force of economic growth, jobs, and competitiveness. Thus, the major role of the university was in the sphere of political and societal contributions, as well as passing on the great traditions of Western civilization to subsequent generations.

However, something changed in the world which posed a real challenge to conventional economic thinking, to growth theorists in particular, and certainly to policymakers. The most economically successful places, such as Silicon Valley in California, did not have an abundance of physical capital, or factories and machines, just as the most striking high-performance companies, such as Apple, SAP, and Microsoft, did not have high levels of investment in physical capital. The paradox confronting economists was, How could such high levels of performance be attained and sustained without an abundance of the factor that seemed to be so important in the Solow Model?

Economist Paul Romer had an answer in his new economic growth theory and models of endogenous growth—it was knowledge and ideas that mattered for economic growth, not just factories and machines.¹² Where do knowledge and ideas come from? While no one knows precisely the answer, it is clear that the universities are an important source of knowledge and ideas. As the United States was confronted by a shift in comparative advantage away from lower-skilled manufacturing and toward knowledge-based economic activity—a shift the press referred to as the “competitiveness crisis” of the 1970s and 1980s—society began to look to the universities for more accountability. Society began to expect universities to contribute to the well-being of society not only by producing people who could contribute to the great Western traditions of civilization and democracy but also by generating knowledge and ideas that would drive economic growth, jobs, and competitiveness in increasingly global markets.

¹¹ Richard R. Nelson, *Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures*, 19 J. ECON. LITERATURE 1029, 1032 (1981).

¹² See Paul M. Romer, *Increasing Returns and Long-Run Growth*, 94 J. POL. ECON. 1002, 1003 (1986).

The main contribution of the endogenous growth models was the explicit inclusion of knowledge in the model, rather than leaving it as an undetermined residual, as had been the case in the Solow model.¹³ Paul Romer, Robert Lucas, and other economists argued that knowledge was a key factor of production, which, along with the traditional factors of physical capital and labor, had a substantial impact on economic growth. Knowledge was considered to be particularly potent as a driver of economic growth because of its inherent propensity to spill over from the knowledge-creating firm or university to other firms and individuals who could apply that knowledge and enhance their productivity.

If knowledge was not considered to be exogenous but could be endogenously created, there was an important role for universities in contributing to the creation of that knowledge that drives economic growth, jobs, and competitiveness in a global economy. A new mandate emerged for universities to contribute to the innovative performance of cities, regions, and entire countries.

II. THE KNOWLEDGE FILTER AND THE BAYH-DOLE ACT

While the models of endogenous growth suggest that investments in knowledge, such as research at universities, will automatically spill over for innovative activity that subsequently generates economic growth, employment, and competitiveness, there are compelling reasons suggesting that the reality is considerably more complicated and nuanced. As U.S. Senator Birch Bayh admonished his colleagues in Congress, investments in creating new knowledge do not automatically translate into innovation and economic growth, because “A wealth of scientific talent at American colleges and universities — talent responsible for the development of numerous innovative scientific breakthroughs each year — is going to waste as a result of bureaucratic red tape and illogical government regulations.”¹⁴

Senator Bayh argued that unless the barriers impeding the spillover of knowledge from universities for private sector commercialization could be knocked down, the return on investment accruing from university research might be too meager to justify substantial investments. Senator Bayh asked, “What sense does it make to spend billions of dollars each year on government-supported research and then prevent new developments from benefiting the American people because of dumb bureaucratic red tape?”¹⁵

¹³ See Robert E. Lucas, Jr., *On the Mechanics of Economic Development*, 22 J. MONETARY ECON. 3, 6-7, 12 (1988); Romer, *supra* note 12, at 1003-04.

¹⁴ ASS'N OF UNIV. TECH. MANAGERS, RECOLLECTIONS: CELEBRATING THE HISTORY OF AUTM AND THE LEGACY OF BAYH-DOLE 5 (2004) (quoting Senator Birch Bayh) (internal quotation marks omitted).

¹⁵ *Id.* at 16 (quoting Senator Birch Bayh) (internal quotation marks omitted).

It was not just Bayh who observed that knowledge created from university research does not automatically spill over to generate economic growth. What first became widely known in Europe as the “Swedish Paradox” and later, upon its expansion, as the “European Paradox” was the existence of economic stagnation even in the presence of high investments in research and education.¹⁶

The barriers impeding university research from spilling over into commercialization constitute a knowledge filter. The knowledge filter prevents knowledge from leading, as a matter of course, to innovative activity that triggers economic growth.¹⁷ The more pervasive the knowledge filter, the less that university-generated knowledge will be able to spill over.

Congress’s passage of the Bayh-Dole Act of 1980¹⁸ can be interpreted as a mandate to improve the flow of knowledge from university research to commercialization and innovation. The explicit goal of the Bayh-Dole Act was to facilitate the commercialization of university-generated knowledge by shifting the ownership of the intellectual property produced at U.S. federal agency-funded research centers from the federal government to the universities.

Universities continued to evolve in yet another direction subsequent to passage of the Bayh-Dole Act. Not only had their role expanded from the classical Humboldt model, where knowledge is pursued for its own sake, to a new model where knowledge is sought to solve societal problems and contribute to economic growth, but also universities began to create mechanisms for facilitating the spillover of knowledge for commercialization and innovative activity. Conduits of technology transfer and knowledge spillovers, such as offices of technology transfer, incubators, offices of engagement, and science parks, were created and gained prominence on university campuses.¹⁹

The primary mechanism or instrument thought to facilitate the spillover of knowledge from university scientist research to commercialization and innovative activity is the university technology transfer office (“TTO”). The Bayh-Dole Act did not explicitly create or mandate the TTO, but sub-

¹⁶ See AUDRETSCH, *supra* note 9, at 106.

¹⁷ See DAVID B. AUDRETSCH, MAX C. KEILBACH & ERIK E. LEHMANN, *ENTREPRENEURSHIP AND ECONOMIC GROWTH* 42, 59 (2006); Zoltan J. Acs, David B. Audretsch & Erik E. Lehmann, *The Knowledge Spillover Theory of Entrepreneurship*, 41 *SMALL BUS. ECON.* 757, 765-66 (2013); David B. Audretsch & Max Keilbach, *The Theory of Knowledge Spillover Entrepreneurship*, 44 *J. MGMT. STUD.* 1245, 1246-49 (2007).

¹⁸ Bayh-Dole Act, Pub. L. 96-517, 94 Stat. 3015 (1980) (codified as amended at 35 U.S.C. §§ 200-11 (2012)).

¹⁹ See Phillip H. Phan, Donald S. Siegel & Mike Wright, *Science Parks and Incubators: Observations, Synthesis and Future Research*, 20 *J. BUS. VENTURING* 165, 168-70, 177-79 (2005); Donald S. Siegel, Reinhilde Veugelers & Mike Wright, *Technology Transfer Offices and Commercialization of University Intellectual Property: Performance and Policy Implications*, 23 *OXFORD REV. ECON. POL'Y* 640, 654-55 (2007).

sequent to the Act's passage in 1980 most universities created a TTO dedicated to commercializing university-based research. Virtually every research university has a TTO or similar office today.²⁰

The TTO not only oversees and directs the commercialization efforts of a university. In addition, the TTO is charged with the painstaking collection of the intellectual property that scientists disclose to the university along with the commercialization activities achieved by the TTO. A national association of offices for technology transfer, the AUTM, collects and reports a number of measures reflecting the intellectual property and commercialization of its member universities.²¹

The AUTM has compiled information about the activities university TTOs undertake, which has facilitated the analysis of the Bayh-Dole Act's economic impact in a large body of studies. As numerous studies document,²² the number of inventions at universities receiving patent protection from the U.S. Patent and Trademark Office exploded subsequent to the Bayh-Dole Act's passage in 1980. These studies document that both the absolute number and the share of overall registered patents accounted for by university patents increased dramatically after the Act's enactment.²³

This increased focus on commercializing university research triggered a positive assessment of the Bayh-Dole Act in particular, and the success of universities to foster technology transfer and knowledge spillovers more generally.

Possibly the most inspired piece of legislation to be enacted in America over the past half-century was the Bayh-Dole act of 1980. Together with amendments in 1984 and augmentation in 1986, this unlocked all the inventions and discoveries that had been made in laboratories throughout the United States with the help of taxpayers' money. More than anything, this single policy measure helped to reverse America's precipitous slide into industrial irrelevance.

Before Bayh-Dole, the fruits of research supported by government agencies had belonged strictly to the federal government. Nobody could exploit such research without tedious negotiations with the federal agency concerned. Worse, companies found it nigh impossible to acquire exclusive rights to a government-owned patent. And without that, few firms were willing to invest millions more of their own money to turn a raw research idea into a marketable product.²⁴

A similar assessment of the positive impact of the Bayh-Dole Act suggested that,

²⁰ See Andy Lockett, Mike Wright & Stephen Franklin, *Technology Transfer and Universities' Spin-Out Strategies*, 20 SMALL BUS. ECON. 185, 187-88, 197-98 (2003).

²¹ See Albert N. Link & Donald S. Siegel, *University-Based Technology Initiatives: Quantitative and Qualitative Evidence*, 34 RES. POL'Y 253, 255-56 (2005).

²² See Mowery, *Chicken, Egg, or Something Else?*, *supra* note 5, at 52-55; MOWERY ET AL., *IVORY TOWER*, *supra* note 5, at 132-33.

²³ See MOWERY ET AL., *IVORY TOWER*, *supra* note 5, at 132-33.

²⁴ Opinion, *Innovation's Golden Goose*, THE ECONOMIST (Dec. 12, 2002), <http://www.economist.com/node/1476653>.

[s]ince 1980, the Bayh-Dole Act has effectively leveraged the tremendous value of academic research to create American jobs, economic growth, and public benefit. The Act has resulted in a powerful system of knowledge transfer unrivaled in the world. . . . One would think the combination of public benefit and the productive, job-creating effects of the Bayh-Dole Act would be a winner in every sense.²⁵

However, studies also pointed out that the distribution of university-obtained patents has remained highly asymmetric and skewed over time, so that most universities do not register a significant amount of patent activity.²⁶ Similarly, only a handful of universities actually earn a high amount of revenue accruing from licensed university technology.²⁷ Thus, a more balanced analysis of the impact of the Bayh-Dole Act based on a full assessment of the patent and licensing activities of universities is somewhat more mixed and nuanced.

III. SCIENTIST ENTREPRENEURSHIP

Most of the studies assessing the impact of the Bayh-Dole Act have focused on patents registered by universities and revenue accruing to universities from the licensing of those patents.²⁸ However, considerably less is known about start-ups emanating from universities. Scientist entrepreneurship, as measured by AUTM reports showing new firms that university scientists created, is seemingly modest at best.²⁹ While U.S. universities may have generated a positive performance in terms of inventions registered at the U.S. Patent Office, TTO data collected by AUTM indicate that they have been considerably less successful in generating entrepreneurship activity.

However, conclusions made about the performance of universities in generating scientist entrepreneurship based on the AUTM database may be flawed and systematically understated. The TTOs collect and report to AUTM only information about their own activities—not about university scientists' commercialization activities that do not involve the TTO. The mission of most TTOs is not to measure and document all of the intellectual property and commercialization activities created at their respective university, but rather to facilitate technology transfer and contribute to the univer-

²⁵ See Pradhan, *supra* note 8.

²⁶ See Mowery, *Chicken, Egg, or Something Else?*, *supra* note 5, at 51-56; MOWERY ET AL., *IVORY TOWER*, *supra* note 5, at 130-32.

²⁷ See Mowery, *Chicken, Egg, or Something Else?*, *supra* note 5, at 54.

²⁸ See Phan & Siegel, *supra* note 6, at 80, 82-86, 93-94; Jerry G. Thursby & Marie C. Thursby, *Who Is Selling the Ivory Tower? Sources of Growth in University Licensing*, 48 *MGMT. SCI.* 90, 92, 99-100 (2002).

²⁹ See Rory P. O'Shea et al., *Entrepreneurial Orientation, Technology Transfer and Spinoff Performance of U.S. Universities*, 34 *RES. POL'Y* 994 (2005); Scott Shane & Toby Stuart, *Organizational Endowments and the Performance of University Start-Ups*, 48 *MGMT. SCI.* 154 (2002).

sity's revenues accruing from licensed technologies.³⁰ Thus, the TTO typically measures and records some subset of the overall commercialization activities at universities, especially in terms of scientist entrepreneurship. As Professor Scott Shane points out,

Sometimes patents, copyrights and other legal mechanisms are used to protect the intellectual property that leads to spinoffs, while at other times the intellectual property that leads to a spinoff company formation takes the form of knowhow or trade secrets. Moreover, sometimes entrepreneurs create university spinoffs by licensing university inventions, while at other times the spinoffs are created without the intellectual property being formally licensed from the institution in which it was created.

These distinctions are important for two reasons. First, it is far harder for researchers to measure the formation of spinoff companies created to exploit intellectual property that is not protected by legal mechanisms or that has not been disclosed by inventors to university administrators. As a result, this book likely underestimates the spinoff activity that occurs to exploit inventions that are neither patented nor protected by copyrights. This book also underestimates the spinoff activity that occurs "through the back door"; that is, companies founded to exploit technologies that investors fail to disclose to university administrators.³¹

The concern about the relative paucity of entrepreneurial activity emanating from U.S. universities recorded by the AUTM database is that assessments of the Bayh-Dole Act in particular, and of university research's contribution to knowledge spillovers more generally, will tend to be understated. Such an undervaluation of knowledge spillovers from universities may adversely affect public-policy decisions about research and educational investments in universities.

In order to shed light on the extent to which scientists' entrepreneurial activities are substantially different from what has been established in the literature based on the AUTM-reported data, this Author and Professor Taylor Aldridge proposed a different methodology for identifying and recording the commercialization activities of scientists at universities.³² Studies evaluating technology transfer and university knowledge spillovers based on the AUTM data essentially ask the TTO what it does in terms of commercialization activities. By contrast, Aldridge and I proposed asking individual scientists about their own commercialization activities.³³

This proposed alternative research methodology based on asking scientists rather than the TTO about their commercialization activities was actually implemented through a survey of university scientists who had

³⁰ See Rory P. O'Shea, Harveen Chugh & Thomas J. Allen, *Determinants and Consequences of University Spinoff Activity: A Conceptual Framework*, 33 J. TECH. TRANSFER 653 (2008).

³¹ SCOTT SHANE, *ACADEMIC ENTREPRENEURSHIP: UNIVERSITY SPINOFFS AND WEALTH CREATION* 4 (2004).

³² Taylor Aldridge & David B. Audretsch, *Does Policy Influence the Commercialization Route? Evidence from National Institutes of Health Funded Scientists*, 39 RES. POL'Y 583 (2010); T. Taylor Aldridge & David Audretsch, *The Bayh-Dole Act and Scientist Entrepreneurship*, 40 RES. POL'Y 1058, 1058-67 (2011) [hereinafter Aldridge & Audretsch, *The Bayh-Dole Act*].

³³ Aldridge & Audretsch, *The Bayh-Dole Act*, *supra* note 32, at 1059-60.

been awarded the largest grants from the National Institute of Cancer at the National Institutes of Health.³⁴ Thus, the database used to analyze the commercialization activities of scientists more generally, and scientist entrepreneurship in particular, consisted of commercialization activities the scientists themselves identified, rather than the TTO-based data on which much of the literature relies.³⁵

The most important finding from the scientist database is that nearly one-quarter of the scientists who had patented were entrepreneurs, in that they had started a new business based on their university research.³⁶ This suggests a degree of entrepreneurial activity among this group of university scientists that is considerably more prevalent than had previously been identified.

However, the finding that one in four scientists engages in entrepreneurial activity is also qualified by the highly selective nature of the scientists who were surveyed. Not only were the scientists engaged in research in one scientific field, cancer research, but they also consisted solely of very highly performing scientists, not only in terms of their patent activity but also the magnitude of their funding received from the National Institute of Cancer at the National Institutes of Health.

The question remained, Does such a high prevalence of entrepreneurship among university scientists hold not only across scientists from other fields of research, but also for those who do not necessarily patent or have a high level of grant and publication performance? To shed light on these questions, Aldridge, Desai, Nadella, and this Author created a broader database, containing more scientists, with two main advantages over the earlier university scientist database.³⁷ The first advantage is that the database spans six different scientific fields, as opposed to just one. The second advantage is that it includes a considerably broader and more heterogeneous spectrum of scientists in terms of scientific performance. This broader, more inclusive scientist database was created from 1,899 scientist responses from an online survey administered among 9,150 scientists (response rate of 20.75 percent). The resulting database identifies the number and frequency of scientist start-ups among scientists that received funding from the National Science Foundation (“NSF”) in one or more of the six broad fields of research, between 2005 and 2012. The six scientific fields are (1) civil, mechanical, and manufacturing innovation; (2) environmental biology; (3) computer and network systems; (4) physical oceanography; (5) particle and nuclear astrophysics; and (6) biological infrastructure.

³⁴ *Id.*

³⁵ *Id.*

³⁶ *Id.* at 1060.

³⁷ T. Taylor Aldridge, David B. Audretsch, Sameeksha Desai & Venkata Nadella, *Scientist Entrepreneurship Across Scientific Fields* (2013) (unpublished paper presented at the annual conference of the Technology Transfer Society, Bergamo, Italy, November 8-9, 2013) (on file with author).

In fact, the results from this broader and more inclusive university scientist database support the overall findings that university scientists are considerably more prolific in their entrepreneurial activities than had been reflected by previous studies based on the AUTM data using the information compiled by university TTOs. The prevalence of university scientist entrepreneurship is estimated to be almost 13 percent. Thus, this broader measure based on scientists in six different areas of science receiving financial support from the NSF indicates that well over one in ten scientists are engaged in entrepreneurial activities in that they have started a business based on their scientific research.³⁸

An additional insight is that the particular field of scientific research apparently influences the prevalence of university scientist entrepreneurship. For example, nearly one in four university scientists in computer and network systems exhibit entrepreneurial activity. The propensity for university scientists to be engaged in entrepreneurship is also strong in civil, mechanical, and manufacturing innovation, where the prevalence of scientist entrepreneurship is over 20 percent.³⁹

In fields of scientific research, such as environmental biology, particle and nuclear astrophysics, and biological infrastructure, the propensity for university scientists to start a new business is considerably lower. For example, only 4.6 percent of the university scientists in environmental biology report having started a new business, while the scientist start-up rates are 6.2 percent in particle and nuclear astrophysics and 8.2 percent in biological infrastructure.⁴⁰ Thus, just as it is clear that university entrepreneurship is considerably more prevalent than had previously been thought, it is equally clear that the particular scientific field of research plays an important role.

IV. CONCLUSION

In order to spur technology transfer and knowledge spillovers emanating from university research, Congress enacted the Bayh-Dole Act in 1980. Such knowledge spillovers from costly research undertaken at universities—funded, to a large degree, by the federal government—are as a matter of public policy perceived to be crucial to spurring innovative activity and ultimately economic growth.

Assessments of the Bayh-Dole Act and U.S. universities' performance in generating technology transfer and knowledge spillovers have ranged from the wildly euphoric to remarkably pessimistic. Most of the insights have been gleaned from analyses using data from the AUTM, which collects information from the university offices of technology transfer. In par-

³⁸ *Id.* at 19.

³⁹ *Id.* at 18, 23.

⁴⁰ *Id.*

particular, such studies have shown that American universities have generated at best a paucity of entrepreneurial activity, leading some to challenge the efficacy of technology transfer at U.S. universities.

This Article has instead shown that, based on data collected from scientists themselves about what they do in terms of commercialization activities, rather than from the university technology transfer offices, one arrives at a very different, and considerably more positive assessment about knowledge spillovers emanating from universities. In particular, a remarkably high level of prevalence of scientist entrepreneurship is identified, suggesting that there is considerably more entrepreneurship emanating from American universities than had previously been thought. It may well be that that scientist entrepreneurship is the stealth conduit of knowledge spillovers from American universities.