MORE THAN MONEY: THE EXPONENTIAL IMPACT OF ACADEMIC TECHNOLOGY TRANSFER

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Academic technology transfer in its current form began with the passage of the Bayh–Dole Act in 1980, which allowed universities to retain ownership of federally funded intellectual property. Since that time, a profession has evolved that has transformed how inventions arising in universities are treated, resulting in significant impact to US society. While there have been a number of articles highlighting benefits of technology transfer, now, more than at any other time since the Bayh–Dole Act was passed, the profession and the impacts of this groundbreaking legislation have come under intense scrutiny. This article serves as an examination of the many positive benefits and evolution, both financial and intrinsic, provided by academic invention and technology transfer, summarized in Table 1.

Key words: Technology transfer; Innovation; Bayh–Dole; Commercialization; Start-ups; Technology licensing; Academic innovation

INTRODUCTION

Technology transfer is defined as "the process of transferring scientific findings from one organization to another for the purpose of further development and commercialization" by the Association of University of Technology Managers (AUTM). This process typically includes sifting for gold (identifying new technology) and knowing what to do with it when you find it (strategies for protection through patents and copyrights, the development of commercialization strategies such as technology development, marketing, and licensing to existing private companies, or the creation of new start-up companies based on the technology) (11).

TECHNOLOGY TRANSFER AND INNOVATION

Innovation is a word frequently used in today's governmental, academic, and corporate lexicons, and it has been defined in varying ways in the literature. A recent article (34) cited a review conducted by Baregheh, Rowley, and Sambrook, who, after analyzing 60 different definitions of innovation, concluded that "Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, services or processes, in order to advance, compete and differentiate themselves successfully in their marketplace" (12). Technology transfer, under this definition, can

Table 1. Summary Table of the Benefits of Academic Technology Transfer

Revenue generation	Unrestricted funds to institution from license income			
	 Direct personal financial benefit to inventors and authors 			
Increased opportunities for funding	 Eligibility for funding by compliance with federal regulations requiring a technology transfer program 			
	 Increased opportunities for interinstitutional and interdisciplinary grants 			
	 Outreach, licensing, and facilitation of new startups yield new funding partnerships 			
	 Increased opportunities for funding sources requiring a commercial partner, for example, SBIR and STTR 			
	 Facilitates establishment of international research relationships 			
Promotes a culture of	Successes increase university brand and prestige			
entrepreneurship and	Enhances university fundraising efforts			
innovation	 Opportunities to strengthen donor ties by engagement with startups 			
	Positively factors into high level recruitment efforts			
	Positively affects retention of high-producing and high-potential faculty			
Student success	 Provides opportunities to participate in real-world translational research 			
	 Provides exposure to the process of obtaining intellectual property protection 			
	Strengthens prospects of finding jobs and being successful			
Public benefit	 Fulfills the university's larger missions to address social, medical, environmental, or technical problems 			
	Improves the quality of life			
Economic development	Revenue from university licensing positively affects the US economy			
	Brings money into the state or region			
	Aids in the retention of local talent			
	 New university startups create high-wage jobs 			

be seen as a critical component to facilitating and sparking innovation within universities, with commercial partners, and in the regions that surround them.

ORIGINS OF UNIVERSITY TECHNOLOGY TRANSFER

University technology transfer effectively began in 1980 when the initial Bayh-Dole legislation was passed (37). This landmark legislation gave universities the right to own and license their federally funded intellectual property to commercial partners. It is important to note that enriching universities was not the goal of Bayh-Dole. Technology transfer became the responsibility of the universities in exchange for receiving federal research and development (R&D) funding based on the recognition that the incentives of the patent system would be a critical component in transforming academic research into products (3). Prior to Bayh-Dole, the federal government owned all discoveries that arose under federally sponsored research, and fewer than 5% of the 28,000 federally owned patents had been licensed to industry (21).

A profession evolved following the passage of this landmark legislation that has transformed the way inventions arising in universities are treated. In his introductory letter to the 2011 AUTM Licensing Survey, past AUTM president Todd Sherer, Ph.D., CLP, concluded "The Bayh-Dole Act is working," a statement that continues to hold true in the survey's most recent 2012 data from 82 institutions reporting \$36.8 billion of net product sales generated, and start-up companies from 70 responding institutions provided work for 15,741 full-time employees (7,8). That same 2012 survey reported steady increases in licensing, start-ups, and cumulative active licenses: 40,007 cumulative active licenses, 5,145 issued US patents, 6,372 new licenses and options executed, 705 new start-up companies formed, and \$2.6 billion total income received (8) (see Tables 2 and 3 for data from 2008 to 2012).

In addition to pure statistics, AUTM presents realworld examples of the impacts of technology transfer in its Better World Project and Put A Face On It videos. The Better World Project features inspiring stories about university technologies that make the world a better place. The website features stories covering a wide range of technologies and impacts,

Table 2. Licenses and Options Executed and Cumulative Active Licenses by US Respondents, 2008–2012

	2008	2009*	2010	2011	2012	2008–2012
No. of respondents reporting licenses and options executed	190	179	180	183	192	N/A
Licenses and options executed	5,132	5,328	5,362	6,051	6,372	28,245
No. of US respondents reporting cumulative active licenses	185	172	174	177	184	N/A
Cumulative licenses active	32,622	33,523	38,528	38,600	40,007	N/A

Source: Association of University Technology Managers (7,8).

such as improved treatments for HIV, better lithium ion batteries, affordable solar energy designs, and smartphone applications that steer drivers toward safety (10). The Put A Face On It videos were unveiled by AUTM at their annual meeting in February of 2014 to enhance awareness of the benefits of technology transfer by featuring the people who benefit from university-developed innovations.

Despite impressive statistics and tangible examples, the profession has recently drawn attention from critics and is the subject of a wave of negative articles and proposals seeking to "remedy" or "correct" a system portrayed as broken and inefficient (25). Recent news titles include: "Universities Struggle to Make Patents Pay," "Why Are Universities Trying to Limit Access to Breast Cancer Tests?" and "Universities Undermine Supreme Court Ruling" (6,22,23; additional examples 4,5,13,30). Notwithstanding this negative criticism, the real tangible and intangible benefits for society and universities created by the Bayh–Dole Act significantly outweigh the negative perceptions and challenges faced by the profession. Such advantages are seen in the gradual transformation of innovations resulting from billions of dollars of federally funded research once lying dormant on the shelves of government that are now being used

to make an impact on society. Perhaps there is no starker example of the impact of Bayh-Dole than when one considers the translation of basic research into new therapeutics to treat a human disease. Prior to Bayh-Dole, when the government took control of inventions away from universities, no new drugs were commercialized from federally funded university research. However, since the passage of the act, more than 153 drugs that started in university laboratories have been approved by the Food and Drug Administration to treat diseases ranging from cancer to HIV. Moreover, in 2012 alone, 705 new companies were created based on university patented inventions and 591 new commercial products were launched for consumer use. Within the underappreciated story of changes in the wake of the passage of Bayh–Dole comes the realization of true innovation in the profession's evolution and response to a complicated system, impacting people's lives, the environment, the economy, and society as a whole (2,33).

BENEFITS OF ACADEMIC TECHNOLOGY TRANSFER

An active academic technology transfer program provides support and benefits to the individuals in

Table 3. Start-ups Formed and Primary Place of Business, 2008–2012

	2008	2009	2010	2011	2012
Total start-ups formed	595	596	651	671	705
Primary place of business-home state	430	435	498	487	554
Home state location as percentage of total	72.3%	73.0%	76.5%	72.6%	78.6%

Source: Association of University Technology Managers (7,8).

^{*}Note that the significant market drop and recession affected technology transfer, as it did most other industries at this time.

the university community, the institution where the program resides, the surrounding community and region, the country, industry partners, and the public. The goal of this article is to provide an overview of these benefits and to return attention to the support and initiatives that are needed to improve outcomes and advance innovation at this critical time in the US.

Revenue Generation

The first benefit highlighted in Table 1 is revenue generation. In the past, it was generally assumed that the best measure of the impact of technology transfer was licensing income, and therefore, the most successful technology transfer offices were those pushing for the highest return and generating the most income on deals. This commercial approach, however, does not take into consideration the academic environment or the fact that universities will engage in activities that create a financial loss if they fit within an institution's mission of education, research, and community engagement (17,20).

In a 2011 National Research Council (NRC) report, the principle findings recognized that the first goal of university technology transfer is the expeditious and wide dissemination of university intellectual property for the public good. This same report noted that the transition of intellectual property takes place through a number of mechanisms, listing eight. While the report recognized that licensing was often the most discussed, it was listed last among the eight and was explicitly stated as not the most important (28).

While the statistical likelihood of blockbuster revenue may be small, the benefit received by a number of institutions from significant yearly revenue streams should not be discounted. As academic funding from state and federal sources is decreasing, universities themselves are now more frequently looking to technology transfer to find profitable technologies that will augment shrinking funding opportunities. As noted in Table 1, one of the benefits of licensing revenue is that it affords relatively unrestricted funds for an institution, which can be significant for public institutions that often have state or otherwise restricted funding (29). These unrestricted funds provide an opportunity for investment and expansion that might not be possible with traditional fund sources. Under most programs, inventors and authors benefit personally and also are provided a portion of the funds received for further unrestricted research at the institution.

AUTM reported a total licensing income for US institutions of \$2.6 billion in 2012, showing an increase from the preceding year (8) (Table 4). The reality is, however, that few institutions make significant revenue from technology transfer. Of the approximately 145 universities that have responded to AUTM's licensing survey over the past 20 years, only about 9 or 10 of them have consistently made blockbuster amounts of money (18). In 2012, only 224 out of 40,007 active licenses generated more than \$1 million, only 0.6% of the total (8). The percentage over \$1 million has remained relatively consistent over the years (17). These revenues also provide direct financial benefits for the authors and inventors who participated (Table 1).

In a review of technology transfer offices from US academic institutions, Abrams, Leung, and Stevens found that over half of the technology transfer programs bring in less money than the costs of operating the program, and only 16% are self-sustaining after distributions to inventors and costs (1). So are technology transfer offices failing, or are the benefits more complicated than just the dollars and cents?

Table 4. Total License Income and Licenses and Options Yielding Income by US Respondents, 2008–2012

	2008	2009	2010	2011	2012
No. of US respondents (total license income)	188	180	182	186	194
Total license income (\$ millions)	\$3,444	\$2,326	\$2,396	\$2,458	\$2,625
Running royalties (\$ millions)	\$2,303	\$1,618	\$1,382	\$1,451	\$1,889
Cashed-in equity (\$ millions)	\$44	\$24	\$63	\$65	\$64
No. of US respondents (licenses and options yielding income)	189	178	178	182	192
Licenses/options yielding income	15,498	16,331	16,205	17,103	18,295

Source: Association of University Technology Managers (7,8).

These statistics realistically reflect the stage of the technologies being disclosed to universities and the insufficient funding available to address the gaps between early stage research and technology ready to be commercialized. The amount of licensing income generated is not under the technology transfer offices' direct control due to the efficacy of the technology, the market, and the licensing company's efforts (17).

Increased Opportunities for Funding

The activities of technology transfer, such as licensing, facilitation of start-ups, development of new partnerships, tangible stories, and research commercialization and jobs, provide opportunities to increase funding at the institution, as highlighted in Table 1. In order to be compliant with federal regulations and eligible for funding, it is a requirement of federal and other opportunities that universities have technology transfer programs to manage the technologies that arise (9).

Technology transfer activities increase opportunities for federal funding, as it is more frequently becoming a required component of the grant opportunity, such as NSF's I-Corps program. As more funding opportunities become interinstitutional and interdisciplinary, technology transfer programs have fostered cooperation and, often, collaboration among universities to move technologies forward (18).

The activities of outreach, licensing early stage technology, and facilitation of start-ups bring new companies to work with the institution, resulting in long-term partnerships that ultimately benefit the institution more than the initial early stage, high-risk technology that facilitated the partnership. While that initial technology may never reach the marketplace, additional research contracts, student educational experiences, and potential employment opportunities will continue to develop. These new start-ups and companies also provide the opportunity for additional types of funding opportunities, such as Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), and analogous state-sponsored programs that require a commercial partner.

An educated and experienced technology transfer program facilitates the development of partnerships that will attract increased corporate research support. One of the key factors in that interaction will be how intellectual property is handled, and technology transfer officers are frequently at the forefront as these new relationships are being established and structured. Ultimately, it can be more cost-effective for industry to license research developed by university researchers with experience working in the field than to develop a new team and research program internally (29).

With issues such as sequestration and the decrease in federal funding opportunities, universities are also looking beyond the borders of the US and seeking to expand their research base internationally. Technology transfer and the management of intellectual property will be a critical piece in establishing those research relationships. Because of economic incentive programs and opportunities to assist in the development of technology transfer operations around the world, the existence of a strong technology transfer program also directly enhances the potential for international collaborations.

Promotes a Culture of Entrepreneurship and Innovation

An engaged technology transfer program promotes a culture of entrepreneurship and innovation in which faculty are rewarded and supported in their research efforts (Table 1). Practical application of their research and a measure of its effects and benefits to society are what many faculty members are looking for as a result of their research (29). These successes enable universities to add to their brand by being innovative and entrepreneurial, which can translate into tangible increases in fundraising and enhanced faculty recruitment and retention.

A unique and significant example of the importance of these activities to researchers is the 2010 formation, rapid adoption, and evolution of the National Academy of Inventors (NAI) as an organization to encourage and honor academic innovation (27). The NAI was formed as a 501(c)(3) nonprofit member organization comprised of US and international universities and governmental and nonprofit research institutes to recognize and encourage inventors who have a patent issued from the US Patent and Trademark Office (USPTO). The NAI has over 3,000 individual inventor members and fellows spanning more than 200 institutions. Its mission is to enhance the visibility of university

and nonprofit research institute technology and academic innovation, encourage the disclosure of intellectual property, educate and mentor innovative students, and encourage the translation of the inventions of its members to benefit society. The NAI is an academic collaborator with the USPTO.

Increased Prestige and Fundraising Efforts

Another important benefit of technology transfer is the prestige and recognition for discoveries made at the institution. Having a successful technology transfer program and bringing technologies to the public can positively affect a university's reputation (29). While not all discoveries cross the million dollar mark in revenue per year, the value of having products developed at the institution demonstrates to the community in a tangible way the impact of research activities that often may seem esoteric and difficult to understand.

The tangible translation of cutting-edge research and innovation to the commercial marketplace is exemplified by the story of KeriCure, Inc. For Dr. Kerriann Greenhalgh, the journey began 9 years ago while a Ph.D. student in organic chemistry at the University of South Florida (USF), working on a drug delivery polymer technology (38). This project was developed with \$1.3 million in federal and state research funding that was brought into the state of Florida by USF researcher Dr. Ed Turos. Working together with USF's technology transfer office, Turos and his research team filed patent applications to protect the technology with the intent of developing commercial products in the future.

Noting the lack of over-the-counter wound care products and the unique qualities of the polymer, Greenhalgh envisioned developing a unique topical product for the skin. After graduating from USF, she worked as a research scientist for USF start-up company MiMedx Group, Inc., gaining valuable experience and insight as she took a product from concept to FDA in 3 months. In 2011, Greenhalgh approached the USF technology transfer office to launch her own company, KeriCure, Inc., to commercialize the polymer technology she had researched as a graduate student at USF. The technology transfer office worked closely with KeriCure to put a license in place that would grant exclusive rights to the drug delivery technology to the new company (38).

Today, KeriCure is dedicated to developing topical products designed to improve healing, prevent and treat infection, and reduce scar formation. Its top product to date is KeriCure's liquid bandage, a solid but elastic barrier that mimics properties of the skin by providing a breathable film that protects damaged tissue. KeriCure is the only company with this patent-pending technology to bind bioactive molecules to a polymer delivery system. The product had an initial launch as a skin protectant available in retail stores and online. Sales and distribution of the skin protectant line have already begun, with the first major sale to Kroger stores in the southern US for 7,200 units of the KeriCure Skin Protectant and, more recently, to Publix Super Markets, Inc. (38).

Universities often use successful technology transfer examples to enhance their fundraising efforts. Commercialized technologies from an institution provide a real-world benefit and clear message for alumni and supporters. Universities are now starting to launch crowd-funding sites to advance their research projects and technologies through targeted donations (16). Opportunities to work with start-up companies provide additional engagement and a means by which donors can participate and give back to the university community (29).

Faculty Recruitment and Retention

One of the hallmarks of a strong research institution is the quality of its faculty. A frequent criterion of high-level recruits is that the institution should have a strong technology transfer program that will help faculty members translate their research to the marketplace (18). Potential recruits want to know who they will be working with and what opportunities will be facilitated for industry contracts, startups, and commercialization (29). These same factors play a significant role in the retention of "star" or high-potential faculty. Including patents, licensing, and commercialization activity in the criteria for tenure and promotion is also important for faculty recruitment and retention, as reported in the *Proceedings of the National Academy of Sciences* by Sanberg et al. and others (32,35).

Student Success

A significant aspect of a university's mission is the education of undergraduate and graduate students and postdoctoral scholars. A strong technology transfer program provides opportunities for students (Table 1) to participate in real-world translational research, gain experience in the process of obtaining a patent, and work with industry, start-ups, and manufacturers (18). Technology transfer also provides expanded job opportunities beyond traditional academic careers and is an avenue to enhance and build on their educational experience. These experiences strengthen their prospects of finding highwage jobs and, ultimately, of being successful (19). Additionally, new courses are emerging at many universities in entrepreneurship, intellectual property, and technology transfer, drawing both new and nontraditional students.

Bytelight was founded by an undergraduate Boston University (BU) engineering student Aaron Gannick, who was advised by BU professor Thomas Little, director of the Smart Lighting Engineering Research Center. Gannick devised a novel use for low-communication bandwidth light-emitting diode (LED) lights: indoor position location and communication. Bytelight was incubated at the BU Photonics Center Incubator and mentored via the BU Kindle Mentoring Program. Bytelight's technology was chosen for the BU MBA class "Strategies for Bringing Technologies to Market," taught by one of the authors of this article. The company has since raised \$4 million in venture capital and has innovative products on the market. Bytelight is a classic example of student start-up success as a result of university research and technology transfer and entrepreneurship support (14).

Public Benefit

Universities have a mission and responsibility to impact big social, medical, environmental, and technical problems even when it does not directly increase their bottom line (18). Innovations from universities have improved the quality of life for people in the US and around the world (31). This sense of altruism is best described by former patent counsel for the Wisconsin Alumni Research Foundation (WARF), Howard Bremer, who stated, "You can't measure the value of lives saved. The royalty doesn't express that" (26).

With advanced technologies that apply insight on how to improve human well-being on the global scale, technology transfer offices can provide unique

examples of opportunities that take inventions out of the laboratory and into the field. One such example is Emory University's ProkoPackTM. Developed by Dr. Gonzalo Vazquez-Prokopec and Dr. Uriel Kitron, both of the Department of Environmental Studies, the ProkoPackTM was designed to be an improvement to current mosquito collection devices. While there may exist a myriad of mosquito collection methods, many of these often costly devices fail to collect a broad variety of adult mosquitoes. This becomes essential in the worldwide effort to improve knowledge on mosquito habits as researchers seek to stem the risk of acquiring mosquito-transmitted diseases, such as malaria, dengue fever, and West Nile virus, which even today affect nearly half the world's population. As an innovative approach, the ProkoPackTM, a small, light, batterypowered mosquito aspirator, is easy to build and makes hard-to-reach locations more accessible due to its maneuverability and compatibility with telescoping extension poles allowing for more accurate counts of mosquito populations and a better understanding of mosquito ecology. Laboratory and epidemiological studies have proven the ProkoPackTM's effectiveness, and the device has outperformed the current gold standard for resting mosquito surveillance worldwide (15).

Economic Development

University technology transfer continues to play an important role in energizing the US economy as set out in Table 1. From 1997 to 2007, university licensing had a \$187 billion impact on US gross domestic product, a \$457 billion impact on US gross industrial output, and created 279,000 jobs (31). Technology transfer efforts also provide economic benefits from increased and expanded funding sources bringing in new federal, private, or international dollars to the region and local community (9).

Commercial benefits aside, the development of new technologies at universities also offers advances impacting sustainability. This is illustrated at the University of Alabama at Birmingham (UAB) with what began as a simple idea to conserve water that has led to an invention that will save the university tens of thousands of dollars and millions of gallons of water. The idea was conceived by the facilities division and led to the creation of a network of tanks

and piping that captures and uses groundwater and condensate from cooling systems. Water piped into buildings on campus and used for air conditioning is collected as condensate that forms on the air handler coils. The condensate is then filtered, cleaned, and pumped into the cooling tower through the chilled water return line. This reduces the cooling water that must be purchased through recycling what they already have. Groundwater is retrieved from campus buildings that accumulate a buildup that has to be routinely pumped to prevent floods, allowing what was once a liability to be a valuable asset. Both systems require little maintenance and have proven so successful that UAB is exploring the feasibility of a patent so others can model the system. So far, savings have been adding up to the tune of about 3 million gallons of water and \$13,000 a month during the summer months alone. It was estimated that from January 2012 through September 2013, 16.9 million gallons of condensate and 15.2 million gallons of groundwater were captured in a sustainability effort that saved the university more than \$138,000. These conservation efforts can benefit the community at large, providing an avenue that will save thousands and promote a green mentality (36).

More and more universities are also fulfilling direct economic development roles nationally and locally. Technology transfer programs are expanding to provide programs that include entrepreneurial training, product proof-of-concept support, and seed stage or gap funding (31). In 2011, Princeton University established an intellectual property accelerator fund to help bridge the gap between embryonic university research and the marketplace.

One area where there is a need to bridge this gap is in computers, where today's silicon-based circuits are beginning to face their limits. Researchers are working on technologies to replace the electrons in circuits with light, which is faster than electrons. While light is already used to transmit information in fiber optic cables over long distances for telecommunications, the application of photonics components has been more elusive. However, a team at Princeton, led by Paul Steinhardt, Princeton's Albert Einstein Professor in Science, and Salvatore Torquato, professor of chemistry, has developed new structures that can do just that. Structures known as hyperuniform disordered solids (HUDS) allow certain frequencies of light flow in specific paths from

chamber to chamber, while blocking other frequencies of light. HUDS contain a complex architecture of internal translucent chambers that permit only certain frequencies of light to travel through the materials. Using precision manufacturing techniques, the researchers can create HUDS with unprecedented light-controlling capabilities. The fundamental research that led to the discovery was supported by the National Science Foundation, and in 2012, the group was awarded a grant from Princeton's IP. The funding attracted the attention of the start-up company Etaphase that licensed the technology and is developing devices small enough to compete with semiconductors in electronic applications (39).

Another economic benefit is the ability to retain local talent and create high-wage jobs through technology transfer (24). Universities, on average, create more than two start-up companies each working day, and these university-based start-ups have longer life spans and raise more capital than non-university-affiliated start-ups (31). While the individual job numbers will be small in the beginning and difficult to capture, an example like the Research Triangle Park in North Carolina illustrates the important role that these new companies can have in job creation and building the economy (18).

CONCLUSION

When an ecosystem exists and all of the elements are aligned, technology transfer can be truly transformational to a university and a community. The profession finds itself at a time when we need to communicate the many benefits of technology transfer and work collaboratively to innovate and continue to evolve as a profession. Calculating a numerical direct return on investment for technology transfer can be complex and difficult if all the tangible and intangible benefits highlighted in Table 1 are considered, but it cannot be denied that individuals, communities, and the US stand to benefit directly from a vibrant technology transfer industry. However, the stool upon which success must rest has more than one leg, and the best opportunity for reaping the benefits arises when all the components come together and are present and supported. Strong and supported technology transfer programs, availability of funding from seed through venture capital, serial entrepreneurs, administrative support, and community engagement all become critical components of the ecosystem affecting its success.

ACKNOWLEDGMENTS: The journal editor and co-author P.R.S. was not involved in the peer review process, including the selection of reviewers and the reviewers' acceptance of this manuscript. The authors thank Lauren Golin and Bridget Maguire for their editorial assistance. The authors declare no conflict of interest.

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