Models and Methods of University Technology Transfer

Department of Economics Working Paper Series

Samantha R. Bradley

University of North Carolina at Greensboro

Christopher S. Hayter

New York Academy of Sciences

Albert N. Link

University of North Carolina at Greensboro

June 2013

Working Paper 13-10

http://bae.uncg.edu/econ/

Models and Methods of University Technology Transfer

Samantha R. Bradley
Department of Economics
University of North Carolina at Greensboro
srbradle@uncg.edu

Christopher S. Hayter
Executive Director, Policy Evaluation and Transformation
New York Academy of Sciences
chayter@nyas.org

Albert N. Link
Department of Economics
University of North Carolina at Greensboro
anlink@uncg.edu

We thank the Richard Lounsbery Foundation for their financial support of this research. We also thank Jerry McGuire of the University of North Carolina at Greensboro, Mark Crowell of the University of Virginia, Gerry Barnett of the University of Washington, and an anonymous reviewer for their comments and suggestions on earlier versions of this paper.

Abstract

This paper argues that a linear model of technology transfer is no longer sufficient, or perhaps even no longer relevant, to account for the nuances and complexities of the technology transfer process that characterizes the ongoing commercialization activities of universities. Shortcomings of the traditional linear model of technology transfer include inaccuracies—such as its strict linearity and oversimplification of the process, composition, a one-size-fits-all approach, and an overemphasis on patents—and inadequacies—such as failing to account for informal mechanisms of technology transfer, failing to acknowledge the impact of organizational culture, and failing to represent university reward systems within the model. As such, alternative views of technology transfer are presented here that better capture the progression of the university towards an entrepreneurial and dynamic institution, and that advance the body of knowledge about this important academic endeavor.

Keywords: technology transfer, entrepreneurial university, intellectual property, patents, innovation, commercialization

JEL Codes: L26, O31, O34,

1. Introduction

Since passage of the Bayh-Dole Act in 1980, universities have increasingly been engaged in technology transfer. Commercialization of university-discovered technologies is a driver of economic growth and universities have played a major role in bringing innovative ideas and inventions to market. Technology transfer activities, which were once practiced mainly by such elite universities as MIT, Stanford University, and the University of California system, are now nationwide. Technology transfer can potentially generate revenues for universities, create research connections between academia and industry, and enhance regional economic growth and development.

There is a large body of literature regarding university technology transfer, mostly focused on institutions that facilitate commercialization such as technology transfer offices (TTOs) or offices of innovation and commercialization (OICs),[1] and mechanisms that facilitate commercialization such as patents, licensing, and spinoffs or startups. However, the process of technology transfer from invention to commercialization is often assumed to be something of a black box. A generalizable model of technology transfer is difficult to find, and one that accurately depicts the subtleties of how knowledge and technology are transferred in practice is arguably non-existent. The extant literature is replete with depictions of traditional models of the technology transfer process, but for the most part these are oversimplified and restricted by the assumption of a linear knowledge flow. As universities become more entrepreneurial and look toward technology transfer into non-traditional fields, there is a need for alternative conceptualizations of technology transfer that are more accurate and realistic than the traditional linear model and that are generalizable to the nuances of the university to which they are applied.

This paper is organized as follows. Chapter 2 presents a schematic of the traditional model of the technology transfer process based on the existing academic and professional literature. The traditional model is characterized by its linearity and formality. The process begins with a discovery by a university scientist and follows a linear path from disclosure to the TTO to the invention being patented, marketed, and licensed to an existing firm for further development and commercialization or to a spinoff or startup company being established around the invention.

[1] There is a burgeoning trend for universities to rename the Technology Transfer Office using terms like *commercialization*, *innovation*, or *outreach*. Herein, we retain the traditional descriptor of TTO.

Chapter 3 offers a review of the extant literature on university technology transfer, and it maps this body of literature according to each process within the traditional linear model. The literature review emphasizes the mechanisms that are used to proceed from one process in the traditional model to the next. However, the traditional linear model has numerous weaknesses and misrepresentations which need to be addressed and remedied.

Chapter 4 addresses the limitations of the traditional model, specifically focusing on its inaccuracies and inadequacies.

After taking these limitations into account, Chapter 5 offers alternative methods and models of university technology transfer. These alternative conceptualizations are intended to represent more accurately technology transfer in practice and to emphasize concepts of academic entrepreneurship and open innovation.

Finally, in Chapter 6, we draw conclusions and discuss the avenues that universities can follow to improve the efficiency and effectiveness of their technology transfer activities. And, we discuss future implications for the institution of university technology transfer.

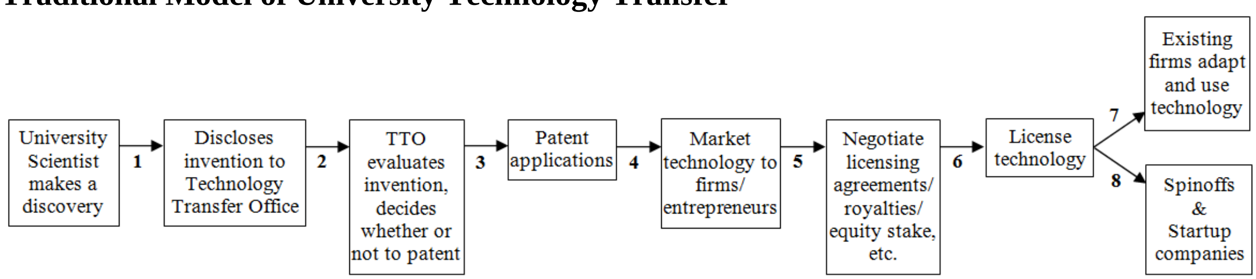
2. The Traditional Model of University Technology Transfer

A schematic of what might be called the traditional model of university technology transfer (UTT), or more simply the traditional model, is presented in Figure 1. This model was constructed as a synthesis of dominant paradigms and the extant literature related to technology transfer within the academic and professional landscape. We refer to this synthesis of existing thought, as illustrated in Figure 1, in its totality as a description of the entire technology transfer process.

This representation has probative value for at least three reasons. One, it is a useful construct for reviewing the academic and professional literature on UTT, which we do in Chapter 3. Two, it establishes a straw man for our discussion in Chapter 4 of the limitations of traditional views about the technology transfer process. And three, it serves as a point of departure for our proposal of an alternative model of technology transfer, which we offer in chapter 5.

The traditional model of the technology transfer process in Figure 1 is illustrated as a linear model, and it begins with the process of discovery by a university scientist (Siegel et al., 2004). The term *scientist* is used as a descriptor for a university researcher. Of course, the academic research could come from any discipline or any department or campus structure.

Figure 1
Traditional Model of University Technology Transfer



Note: Each of the numbered processes will be discussed in detail in later chapters.

The scientist discloses the invention to the university's TTO. Once the invention is disclosed, the TTO evaluates the invention and decides whether or not to pursue acquiring a patent. The TTO must consider the commercial potential of the invention, as well as prospective interest from the public or private sector (Siegel, Waldman, and Link, 2003). If the TTO decides to invest in the invention, the next step is the patent application process. If the patent is awarded, the TTO markets the technology to organizations and entrepreneurs. The goal of this marketing effort is to match the technology with an organization or entrepreneur that/who can best utilize the technology and provide opportunity for revenues to the university.

When a suitable partner is found, the university works with the organization or entrepreneur to negotiate a licensing agreement. The licensing agreement typically includes a royalty to the university, an equity stake in the startup, or other such compensation. When an agreement is reached, the technology is officially licensed. In the final stage of the process, the organization or entrepreneur adapts and uses the technology.

The original invention typically undergoes extensive adaptation during the process to commercialization. The university, and sometimes the inventing scientist, might continue to be involved with the organization or entrepreneur to help develop the technology or to maintain the licensing agreement (Thursby, Jensen and Thursby, 2001).

Several existing paradigms have been useful in crafting the traditional model. Miller and Acs (2012) characterize traditional technology transfer as an organization-centric model that combines Etzkowitz’s (2003b) triple helix model and Kerr’s (2001) concept of the multiversity. Under the triple helix model of university-industry-government relations, reciprocal relationships are formed among the three institutions in which each attempts to enhance the performance of others. The multiversity is a modular institution centered on undergraduate and graduate schools with multiple activities and organizations, including science parks and research institutes, integrated or released depending on the needs of the students, faculty, and regional communities. Miller and Acs’s organization-centric model extends the path from Bush’s implicit linear model (1945) to the Bayh-Dole Act, and achieves technology transfer through connections between university researchers and both federal funding and potential commercial opportunities.

The design of our traditional model is generated from various descriptions and applications of the traditional technology transfer process found in the aforementioned UTT literature. Below, we discuss each process of the traditional model in greater detail.

University Scientist Makes a Discovery

There is a growing emphasis on formalizing technology transfer in universities. Technology transfer is seen as playing an increasingly significant role in stimulating economic development (Siegel, Waldman, and Link, 2003). The catalyst for starting the technology transfer process could come from the research support of the federal government or industry (Bozeman, 2000). Commonly, the university scientist receives a federal research grant. The scientist uses the grant to conduct research and purposely or serendipitously discovers a new product or process technology that might have market potential, thus beginning the technology transfer process.

Alternatively, sometimes industry might initiate a partnership with a university. Etzkowitz (2003a) refers to this as reverse linearity, which starts from commercial and societal needs; that is, firms seek academic resources. Reverse linearity connects the university to external problems, sources of knowledge, and firms seeking academic resources (Etzkowitz, 2003a). Heinzl, Kor, Orange, and Kaufmann (2008) refer to this as contract research, where a contract is formed between the university and industry which defines R&D efforts to be performed. This might include fundamental research, feasibility and prototype studies, experiments, and consulting. It might be more convenient and cost-effective for the firm to contract with the university rather than the firm conducting in-house research (Bell, 1993).

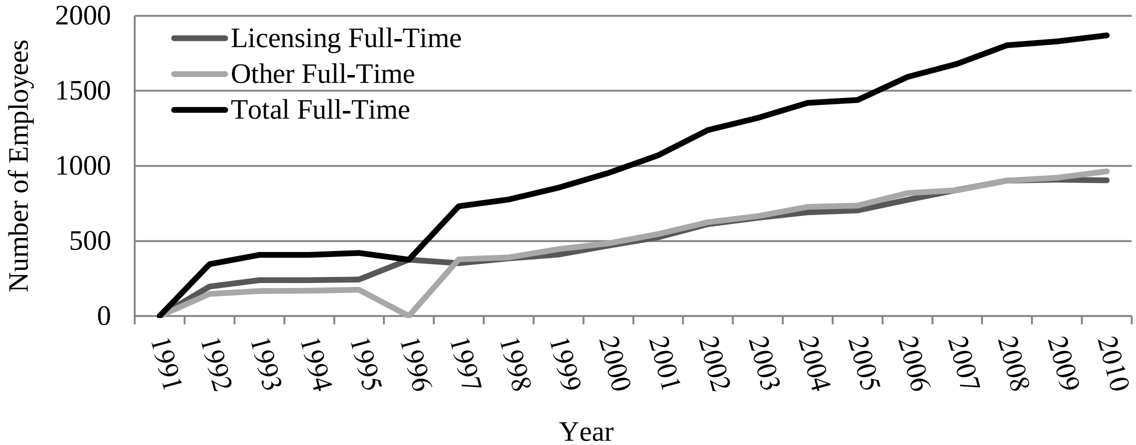
Regardless of what originally facilitates the research, whether it is a federal grant or funding from industry or a foundation, the traditional model of the technology transfer process starts with the discovery of the technology by the university scientist and moves forward on a linear path.

This leads us to the next step of the traditional model.

Discloses Invention to Technology Transfer Office

The Bayh-Dole Act of 1980 (Public Law 96-517, Patent and Trademark Act Amendments of 1980) was instrumental in encouraging universities to engage in technology transfer and ultimately facilitating commercialization of federally-funded university-discovered technologies (Association of University Technology Managers, 2012). The Bayh-Dole Act has led universities to consider technology transfer as a commercial activity (Shane, 2004). Because of the increased emphasis on university technology transfer, most universities have now established TTOs (Friedman and Silberman, 2003). The size of TTOs and the magnitude of their operations have steadily increased over the past two decades, as indicated by the number of full-time employees in TTOs. Figure 2 shows the number of licensing full-time employees and other types of full-time employees in TTOs since 1991 based on data reported by the Association of University Technology Managers.

Figure 2
Full-Time Employees in University Technology Transfer Offices, 1991 – 2010



As stipulated by the Bayh-Dole Act, the federally-funded faculty member who recognizes or discovers a new technology or invention that has commercialization potential is required to disclose the invention to their university's TTO (Friedman and Silberman, 2003). The Bayh-Dole Act mandates that "the contractor disclose each subject invention to the Federal agency within a reasonable time after it is made and that the Federal Government may receive title to any subject invention not reported to it within such time."[2] This second step in the traditional model assumes that once a scientific discovery is made, it is then directly disclosed to the TTO.

However, the rule that university scientists must file an invention disclosure is rarely enforced, and depends largely on incentive structures within the university (Debackere and Veugelers, 2005). Siegel, Waldman, and Link (2003) note that TTO personnel must devote some effort to encourage faculty members to disclose their inventions. The existence of an idea does not guarantee that it will receive the attention necessary for development (Roberts and Peters, 1981). Faculty quality affects the number of invention disclosures, which then influences licensing agreements (Friedman and Silberman, 2003). The traditional model does not consider alternatives to TTO disclosure, such as simply not disclosing, the faculty member bypassing the

---

[2]The Bayh-Dole Act is codified in 35 U.S.C. 200-212 and implemented by 37 C.F.R. 401. "The *contractor* will disclose each subject invention to the *Federal Agency* within two months after the inventor discloses it in writing to *contractor* personnel responsible for patent matters. The disclosure to the agency shall be in the form of a written report and shall identify the *contract* under which the invention was made and the inventor(s). It shall be sufficiently complete in technical detail to convey a clear understanding to the extent known at the time of the disclosure, of the nature, purpose, operation, and the physical, chemical, biological or electrical characteristics of the invention." CFR Title 37 – Patents, Trademarks, and Copyrights. CFR 404.14 – Standard Patent Rights Clauses.

TTO, etc. This is a shortcoming of the traditional model as well as a limitation of the organizational and administrative structure within many universities, as discussed in Chapter 4.

The technology is now in the hands of the TTO, and next the office must decide what to do with it.

TTO Evaluates Invention, Decides Whether or Not to Patent

The role of the TTO is to facilitate commercial knowledge transfers through the licensing to industry of inventions or other forms of intellectual property resulting from university research (Siegel, Waldman, Atwater, and Link, 2004). The TTO centralizes all university invention and commercialization activities by requiring, formally or informally, faculty to coordinate their efforts through the TTO. Generally, faculty must notify the TTO of their discoveries and delegate to the university all rights to negotiate licenses on their behalf (Litan, Mitchell, and Reedy, 2007). Of course, out of the pool of disclosures that the TTO receives and processes only a fraction will move forward to the patent stage. In deciding whether or not to patent, the TTO evaluates the invention on several different levels, including, but not limited to:

- Revenue potential
    - Most universities now explicitly consider the salability of university inventions as part of their patenting decision (Jensen and Thursby, 2001).
    - The most important objective to the TTO is royalties and fees generated (Thursby, Jensen, and Thursby, 2001).
    - Many TTOs focus their limited time and resources on the technologies that appear to promise the biggest and fastest financial return (Litan, Mitchell, and Reedy, 2007).
    - Patenting imposes a cost that, from an economic perspective, is worth incurring only if the royalties from licensing those patents exceed the average cost of patenting (Shane, 2004).
    - University technology transfer offices typically focus on nascent firms in high-technology industries with tremendous promise (Lerner, 2005).
    - TTOs typically focus on short-term cash maximization and are extremely averse to financial and legal risks (Siegel, 2011).
- Licensing potential

    - Many universities now apply for patents conditional on the identification of a potential licensee for the technology (Jensen and Thursby, 2001).
- Academic field of the invention
    - The Bayh-Dole Act has been influential in providing incentives for universities to increase patenting in fields in which licensing is an effective mechanism for acquiring new technical knowledge (Shane, 2004).
    - Certain fields are more likely to have invention disclosures. Some of the most prevalent include pharmaceuticals, engineering, and biotechnology (Thursby, Jensen and Thursby, 2001; Jensen and Thursby, 2001; Geuna and Nesta, 2006).
    - The TTO must understand the field and evaluate where its technology is moving, in order to decide whether or not a patent should be filed on the discovery (Seigel, Waldman, Atwater, and Link, 2004).
- Competitiveness
    - A revolutionary technology is more valuable to industry than an evolutionary one; the more revolutionary a technology, the less likely it is that potential recipients can accomplish similar advances by other means (Goldhor and Lund, 1983).
- Extensibility
    - The discovery can form the basis for a variety of target technologies, products, or processes and can be extended by a firm's research (Goldhor and Lund, 1983). The TTO is more likely to patent inventions that have broad commercialization potential.

Patent Applications

Once the TTO decides to move a disclosure forward, it begins the patent application process. Most universities have limited budgets for filing patents, and as a result the TTO must be selective about which inventions to pursue. Global patent protection is the most expensive type of patent, so universities might choose to apply for a domestic patent, which protects the technology at significantly lower cost (Siegel, Waldman, Atwater, and Link, 2004). Figure 3 shows the minimum costs of acquiring a patent.

Figure 3
Cost of Acquiring a U.S. Patent in 2011

Type of Patent	Basic Filing Fee	Patent Search Fee	Patent Examination Fee	Issue Fee	Maintenance Fee (3.5 years)	Maintenance Fee (7.5 years)	Maintenance Fee (11.5 years)	Total
Provisional	$250.00	--	--	--	$1,130.00	$2,850.00	$4,730.00	$8,960.00
Utility	$380.00	$620.00	$250.00	$1,740.00	$1,130.00	$2,850.00	$4,730.00	$11,700.00
Design	$250.00	$120.00	$160.00	$990.00	$1,130.00	$2,850.00	$4,730.00	$10,230.00
Plant	$250.00	$380.00	$200.00	$1,370.00	$1,130.00	$2,850.00	$4,730.00	$10,910.00

Note: Compiled data from the U.S. Patent and Trademark Office Fee Schedule, effective September 26, 2011. Definitions provided by the U.S. Patent and Trademark Office website.

Provisional patent: provides the means to establish an early effective filing date in a patent application and permits the term “Patent Pending” to be applied in connection with the invention. Pendency lasts 12 months from the date the provisional application is filed.

Utility patent: may be granted to anyone who invents or discovers any new and useful process, machine, article of manufacture, or composition of matter, or any new and useful improvement thereof.

Design patent: may be granted to anyone who invents a new, original, and ornamental design for an article of manufacture.

Plant patent: may be granted to anyone who invents or discovers and asexually reproduces any distinct and new variety of plant.

Maintenance fee: paid 3.5, 7.5 and 11.5 years after the original grant for all patents issuing from the applications filed on and after December 12, 1980. The maintenance fee must be paid at the stipulated times to maintain the patent in force.

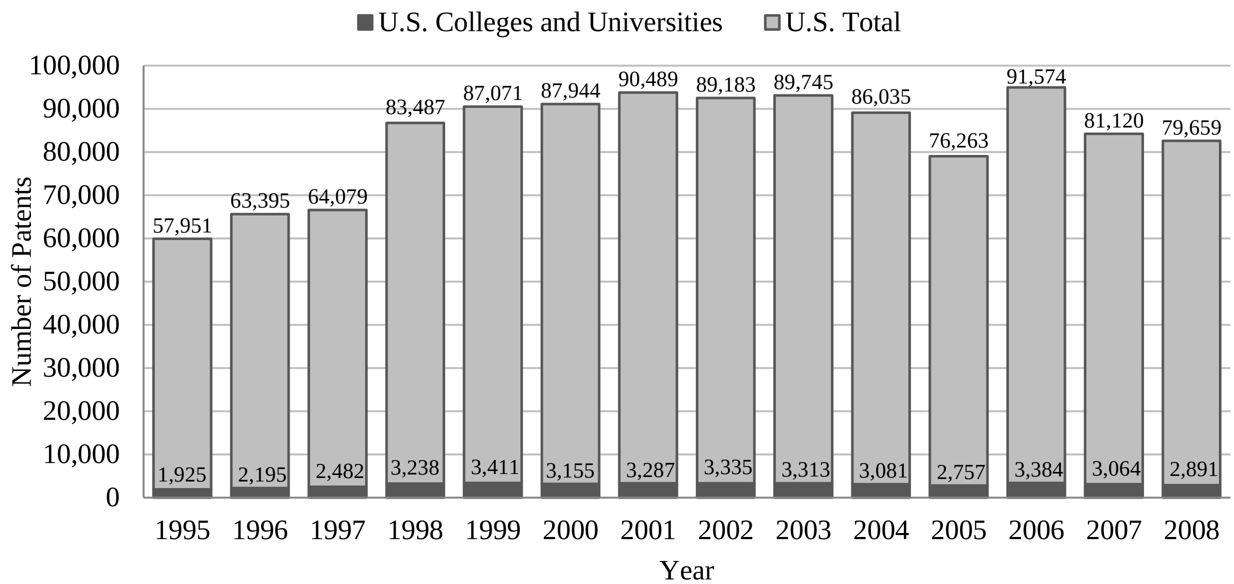
In addition to the basic fees detailed in Figure 3, there are additional costs of acquiring patents. The primary additional cost is legal fees. The TTO typically contracts a patent or intellectual property attorney (having an attorney on staff is unusual due to the high costs it incurs) to conduct a patent search, prepare the patent application, and file the application with the U.S. Patent and Trademark Office (USPTO). The patent search alone can take weeks, in addition to the average 22 month period between application and issuance. Disclosures in certain fields, especially science and medicine, often require the assistance of attorneys with specific knowledge of, and experience in, the field in order to navigate the more complicated aspects of patent acquisition. Attorney fees will vary case by case, but can easily add thousands of dollars to the direct cost of acquiring a patent from the USPTO.

It is common for TTOs to have positions on staff to supplement the external legal work, often described by such a term as *legal assistant*, *licensing specialist*, or *licensing liaison*. It is also common to have a marketing specialist position whose duties include conducting market research to determine if pursuing a patent is commercially viable. These specialized positions can be costly to the office, but they do facilitate successful patent acquisition. Obviously, the costs of acquiring a patent escalate quickly, so it is important for the TTO to be discriminating in the inventions that it pursues.

As technology transfer has become increasingly important to universities, the number of patent applications has risen considerably. According to data from the U.S. Patent and Trademark Office (USPTO), the number of patents awarded to U.S. universities has increased from 1,925 patents in 1995 to around 3,000 by the late 2000s. Figure 4 shows the number of utility patents awarded to U.S. universities by year. Relatedly, the 2010 AUTM U.S. Licensing Activity Survey reports that in 2009, total U.S. patent applications filed increased 2.7 percent. There were 12,281 new U.S. patent applications, and 4,469 U.S. patents issued. Leydesdorff and Meyer (2012) note that the significant increase in university patenting since 2008 is driven largely by ‘inverse foreign investment’ in U.S. patenting, wherein foreign universities in countries like China and Japan file for patents at the USPTO as the U.S. has the most competitive market for high-tech innovations.

An increase in the number of university patents is one indicator of technology transfer improvement (Kim, 2011). However, there is often a lag between the time the TTO applies for a patent and when the patent is actually issued (Thursby, Jensen, and Thursby, 2001); according to the USPTO, the average time to from patent application to patent granted is currently 22 months. Thus, this step of the traditional model could last several years before the TTO is in a position to begin to market the technology.

Figure 4
U.S. Utility Patents Issued to U.S. Universities



Note: Data obtained from the U.S. Patent and Trademark Office report "U.S. Colleges and Universities: Utility Patent Grants 1969-2008," January 25, 2012.

Market Technology to Firms/Entrepreneurs

A major role of the TTO is connecting inventions to firms that want to utilize them. By providing a search mechanism to find the most appropriate sources for sale of knowledge, the TTO helps reduce uncertainty for firms (Etzkowitz, 2003a). TTOs serve as educators to academic entrepreneurs and information brokers to investors (Lerner, 2005). The TTO's primary motive is to safeguard the university's intellectual property while marketing the intellectual property to private firms (Siegel, Waldman, Atwater, and Link, 2004).

When marketing technology to firms and entrepreneurs, the TTO must navigate potential conflicts of values and conflicts of interests between themselves and industry, as well as between themselves and researchers. These conflicts stem from a growing shift from "public good" knowledge regime to "academic capitalist" knowledge regime (Slaughter and Rhoades, 2004). Monetary benefits from patenting and licensing are of great concern to industry and TTOs, while academic scientists wish to gain visibility and reputation from such activities (Baycan and Stough, 2011b). TTOs must balance the traditional tenets of higher education such as preserving academic freedom, creating and diffusing knowledge, and promoting regional economic development, with industry interests such as profit maximization, growth, and competitive advantage (Behrens and Gray, 2001; van Dierdonck and Debackere, 1988; Kumar, 2010).

The characteristics of the technology determine how and to whom it will be marketed. For example, Thursby, Jensen, and Thursby (2001) found that small firms are more likely to take on early-stage technologies, while large companies are more inclined to take on late-stage technologies. It is often beneficial to have a technology transfer agent involved in marketing the technology and mediating the connection between university and industry. These issues are addressed further in Chapter 3.

Connecting university technology with industry is a mutually beneficial arrangement. Technology transfer can be a significant source of revenues for the university and provide industry with important new technologies (Siegel, Waldman, Atwater, and Link, 2004). Faculty members have the opportunity to complement their own research by using licensing royalties and other revenues to fund graduate students, laboratory equipment, and other research tools (Lee, 2000). Academic-industry collaboration might also provide entrepreneurial opportunities for faculty. Technology transfer is beneficial for industry because utilizing university-developed technologies can help maintain a comparative advantage in the marketplace and save R&D time and cost, and being affiliated with a university might provide a halo effect for the firm (Bell, 1993). Also, firms that collaborate with universities have greater access to new university research and discoveries (Lee, 2000). Therefore, the marketing stage is very important in the traditional model because it sets the foundation for an advantageous relationship between university and industry.

Negotiate Licensing Agreements

The next step in the traditional model is negotiating licensing agreements. The university owns the intellectual property rights to the technology and can license the patented technology to a firm (Friedman and Silberman, 2003). Once a suitable organization or entrepreneur is found, negotiations for a licensing agreement can begin.[3] Because formal technology-transfer licensing agreements are typically negotiated before all research is complete and before the commercial

[3]Thursby, Jensen, and Thursby (2001) note that it is common for multiple firms to examine a university's technology, but considerably fewer firms actually become involved in license discussions because there is a "thin" market for early stage technologies.

value of the end result is known, negotiations are based on subjective estimates of the expected value of the return on the innovation (Bercovitz and Feldman, 2006).

The licensing agreement typically includes royalty agreements; the firm using the technology (the licensee), will pay the university a percentage of the revenues earned from using their intellectual property. License issue fees typically range from $10,000 to $50,000 but may be as high as $250,000, whereas royalty rates are typically in the 2 percent to 5 percent of licensing revenues range but may be higher (Bray and Lee, 2000). The agreement could also include securing an equity stake for the university in a new venture based on the licensed technology. Licenses with equity are becoming more common because if even a few of the firms in an institution's portfolio go public, the returns for the university could be enormous (Powers and McDougall, 2005). These agreements generate revenues for the university, which can be used for additional research funding (Siegel, Waldman, and Link, 2003). Sometimes the license agreement will include a follow-on sponsored research agreement in which the firm would provide a specified amount of funding for the university to assist in the development of an embryonic technology into a commercially viable product (Thursby, Jensen, and Thursby, 2001).

License the Technology

Once the license is executed and the technology is transferred, it is developed for commercialization. Firms typically desire exclusive licenses in order to maintain proprietary control of the technology, but non-exclusive licenses can be granted as well depending on scope, sector, or geography (Siegel, Waldman, and Link, 2003; Bercovitz and Feldman, 2006). Licensing can be exclusive or non-exclusive (Lee and Win, 2004). Licenses also vary in terms of publication delay allowances, duration of protection, and future option rights (Bercovitz and Feldman, 2006). The university will often license the technology before it is protected by a patent (Thursby, Jensen, and Thursby, 2001; Siegel, Waldman, and Link, 2003). In the traditional model, the technology can either be licensed to an existing firm, or a new firm—a spinoff or a startup—could be launched around the technology.

Existing Firms Adapt and Use Technology

Most university inventions that are disclosed and licensed are embryonic in nature and require significant further development. University inventions are often years away from commercialization (Thursby, Jensen, and Thursby, 2001). The average commercialization time from university to industry is 4.17 years, and 4.27 years to new ventures (Markman, Gianiodis, Phan, and Balkin, 2005). Academics in the university conduct research which sets the foundation for new innovations. However, it is important to note that a large gap remains between laboratory demonstrations of inventions and commercial utilization (Goldhor and Lund, 1983). Transferring the source technology involves adaptation and utilization that may change the technology into something quite different from the original disclosed invention (Goldhor and Lund, 1983).

In this step of the traditional model, the firm adapts the university's technology for commercial use. This typically requires ongoing, maintained cooperation between the university academics and the firm in order to develop a commercially viable product (Jensen and Thursby, 2001).[4] A university discovery could show marketable potential, but at the time it is patented and licensed it is usually in an early stage of development and thus the firm cannot yet commercialize it. The firm is interested in utilizing the technology and is willing to invest in it, but the invention cannot reach fruition without further development. Successful technology transfer does not end when the technology is handed over to industry, but rather it requires utilization of the technology in new products, processes, or innovative organizational changes (Heinzl, Kor, Orange, and Kaufmann, 2008). Also, firms are concerned with the time to market because the benefits from innovation may depend on how quickly a new product can be developed (Siegel, Waldman, and Link, 2003). Therefore, specialized faculty knowledge and involvement is necessary for firms to be willing to license and develop early stage technologies (Thursby, Jensen, and Thursby, 2001).

Spinoffs and Startup Companies

Spinoffs and startups provide academic entrepreneurs with an alternative pathway for disseminating and commercializing research, often when they are unable to license their technology to large companies or an external entrepreneur (Lowe, 2002). The technology might be embryonic or seem too high-risk to attract investors. Sometimes a spinoff or startup is the only option for developing a technology and without the creation of a new entity, that technology

[4]Although it is widely acknowledged that continual academic-industry cooperation is typically necessary when developing an invention, in contexts where the firm has strong links with the associated scientific and technology communities, inventor involvement may be less critical for commercialization (Mowery, 2009).

might never be commercially viable (Shane 2004a). Furthermore, spinoffs and startups appropriate the value of their innovation and can provide opportunities for additional funding mechanisms to further their research agenda (Bercovitz and Feldman, 2006).[5]

In some situations, a new firm is created specifically to sell the technology invented in the university's laboratory (Harmon, Ardishvili, Cardozo, Elder, Leuthold, Parshall, Raghian, and Smith, 1997). The license is granted to an entrepreneur who can launch the startup firm based on the transferred technology (Siegel and Phan, 2005). Again, the university scientist could be the entrepreneur who founds the startup, or they could serve on the board of directors, be a technical consultant, etc. Or, faculty members might have an equity stake in the startup company (Siegel, Waldman, and Link, 2003).

Wright, Clarysse, Mustar, and Lockett (2007) argue that the process of spinoff development is an iterative one over the different phases of the venture's growth, and policy actions must be differentiated according to the particular phase of development. They describe the essential elements of creating a dynamic spinoff sector, especially noting the importance of TTOs, incubators, and seed capital funds in or around universities and public research institutions. The way in which a TTO is organized has a direct impact on the kind of spinoffs that will be created.

Spinoffs often develop within a university's research park (Siegel and Phan, 2005). Spinoff creation benefits from support structures like incubators or science/research parks within or close to the university (Heinzl, Kor, Orange, and Kaufmann, 2008). Not all universities have a research park, but for those that do, university spinoffs are more likely to originate in science/research parks that are closest to the university, as well as in technology-focused science/research parks such as those centered on biotechnology (Link and Scott, 2005).

There are various motivations behind the decision for academics to pursue entrepreneurial activities. Profit is the most obvious motivation, but there are also plenty of non-pecuniary motivators (Hayter 2011). Cassar (2007) observes that intrinsic motives–including self-realization, prestige, career advancement, and independence–appear to be dominant factors in the decision to undertake venturing activity. Di Gregorio and Shane (2003) describe micro- and

---

[5] There is a distinction between spinoffs and startups:
Startups are companies created by licensing an early-stage invention to an independent entrepreneur (who is not necessarily a university faculty member), with the goal of developing the company around the growth and commercialization of the technology.
Spinoffs are new companies formed by individuals (faculty members) related to the university or university research park to develop a technology that was discovered in, and is transferred from, the parent organization.

macro-level factors that can motivate new company creation. Micro-level factors include attributes of the invention and inventors' career experience, psychological makeup, and research skills. Macro-level factors include technology regimes, strength of patent protection, and universities' intellectual property (IP) and human resource policies. Lockett and Wright (2005) find that the primary motivation for university scientists is recognition within the scientific community, so if universities place more value on commercialization activities and offer more rewards and incentives for scientists who engage in technology transfer, the scientists' prestige motivation will better align with universities' spinoff and startup goals.

There can also be a distinction between opportunity and necessity entrepreneurship, as differentiated by the Global Entrepreneurship Monitor (Reynolds, Camp, Bygrave, Autio, and Hay, 2001). Opportunity entrepreneurship is voluntarily pursuing a business opportunity for a specific market opportunity, while necessity entrepreneurship is pursuing a business opportunity because it is the best, although not necessarily the preferred, option available for employment.

The benefits of concluding the technology transfer process with a spinoff or startup company include the potential for the spinoff or startup to generate a long-term payoff, create jobs, and generate high returns if the firm is taken public (Siegel and Phan, 2005). The university connection and proximity is advantageous for the spinoff because the university provides skilled labor, specialized facilities, and topical expertise (Bercovitz and Feldman, 2006). Emphasizing spinoffs as a technology transfer strategy can lead to an agglomeration of high-tech firms around the university, eventually resulting in a technopolis or technology-based cluster (Rogers, Takegami, and Yin, 2001). One example of this is the technopolis that emerged in Austin, Texas around the University of Texas at Austin in the late 1980s and early 1990s. Local and regional economies with a sophisticated technology infrastructure and populated by startups are better positioned to attract knowledge-seeking investment from multinational corporations (O'Shea, Allen, O'Gorman, and Roche, 2004). The potential rewards from spinoffs and startups create incentives for universities to engage in entrepreneurial activities.

The following chapter describes the processes within the model by means of a review of the extant literature.

3. Methods of University Technology Transfer

This chapter builds on the traditional model in Figure 1. Specifically, the extant literature on UTT is reviewed in the eight tables that follow with an emphasis on the methods used from moving from one process in the traditional model to the next.

Literature Related to University Disclosures

Table 1 shows the extant literature regarding the first process in the model, moving from a faculty member's discovery to engaging the university's TTO. This process involves the faculty member's decision to disclose and the start of the relationship between the scientist and the TTO.

There are several factors captured in this first process that determine whether or not the traditional technology transfer process successfully begins. These include the catalyst of federal, industry, or foundation funding and the disclosure stipulations of the Bayh-Dole Act; the faculty member's resources such as sufficient knowledge about how the technology transfer process at his/her university works; the perceived ease of disclosure and interacting with the TTO; and whether their university has a culture that encourages innovation.

Table 1
Academic Literature Related to University Disclosures

Author(s)	**Key Findings**
Bozeman (2000)	The federal government provides the majority of R&D funding for universities, although university-industry collaboration is on the rise.
Feldman and Desrochers (2003)	The historical structure and mission of the university can affect how it approaches the issue of technology transfer. A university that has historically not been concerned with enhancing the local economy or partnering with industries probably will not engage in as much or as effective technology transfer.
Friedman and Silberman (2003)	The Bayh-Dole Act requires a university's faculty members, students, or staff who recognize or discover a new technology or invention that has commercialization potential, to disclose the invention to their TTO.
Harmon, Ardishvili, Cardozo, Elder, Leuthold, and Parshall	The technology transfer process is a linear sequence of steps, from development to negotiations to transfer of the

(1997)	technology, in one direction from the university to the private buyer.
Jensen, Thursby, and Thursby (2003)	Whether the inventor discloses, and at what stage, is a function of the equilibrium license income and level of sponsored research, the inventor's rate of time preference, and faculty quality.
Link, Siegel, and Bozeman (2007)	Formal technology transfer mechanisms embody, or directly result in, a legal instrumentality such as a patent, license or royalty agreement. An informal technology transfer mechanism facilitates the flow of technological knowledge through informal communication processes, such as technical assistance, consulting, and collaborative research. University incentives need to be properly aimed towards keeping tenured faculty members involved in formal technology transfer activities.
Markman, Gianiodis, Phan, and Balkin (2005)	Universities rely on employment contracts and an honor system that call for faculty to disclose discoveries to their university TTO in a timely manner. This suggests that (a) disclosure and subsequent engagements with licensees depend on faculty who self-select into this process and (b) faculty who self-select to disclose and support commercialization efforts represent only a small subset of the research faculty population.
Owen-Smith and Powell (2001)	Faculty decisions to disclose are shaped by their perceptions of the benefits of patent protection. The incentives are influenced by the perceived costs of interacting with TTOs and by institutional environments (whether or not they are supportive to commercialization).
Roberts and Peters (1981)	Although a majority of faculty can be expected to generate ideas of potential commercial value, only a small fraction act to commercialize on their ideas. Commercialization behavior is linked to background characteristics of the person and is predicted by previous related behaviors.
Siegel, Waldman, and Link (2003)	The first stage of the technology transfer process is scientific discovery, after which the Bayh-Dole Act stipulates the scientist must file an invention disclosure with the TTO.
Thursby, Jensen, and Thursby (2001)	Certain fields, such as medicine, engineering, nursing, and science, are more likely to have invention disclosures.
Thursby and Thursby (2002)	Disclosure involves faculty providing the TTO with information on the invention and inventors, funding sources, potential licensees, and barriers to patent potential. Invention disclosures are a function of faculty size, research funds, the number of full-time equivalent personnel in the TTO, faculty propensity to disclose, probability of invention discovery.

	Propensity to disclose reflects direction of faculty research and faculty willingness to disclose, and can be influenced by policies and practices of university administrations as well as perceived potential for monetary gain.

Literature Related to the Role of Technology Transfer Offices

Table 2 summarizes the literature associated with the second process in the traditional model. In the second process, the invention is in the hands of the TTO to evaluate and decide whether or not to pursue a patent. The TTO is the main facilitator of the traditional model, accountable for moving the invention through the majority of the processes. Process 2 in Figure 1 encompasses the TTO's initial function of taking responsibility for the invention and getting the technology transfer process off the ground. The literature summarized in Table 2 describes the basic characteristics and functions of the TTO and its role within the university.

Table 2
Literature Related to the Role of Technology Transfer Offices

Author(s)	**Key Findings**
Bercovitz, Feldman, Feller, and Burton (2001)	Technology transfer activities (eliciting and processing invention disclosures, licensing university-created knowledge, seeking additional sponsorship of R&D projects or a combination of these three) are shaped by the resources, reporting relationships, autonomy, and/or incentives of TTOs.
Clarysse, Wright, Lockett, Mustar, and Knockaert (2007)	Most countries enacted Bayh-Dole-like legislation, which grants universities the rights over their own IP. The ownership of IP rights by TTOs relative to that of faculty has increased. The age and size of the TTO is directly related to the time elapsed after the passing of a Bayh-Dole type of act. TTOs spend up to 80% of their time on IP related issues. As a result, IP awareness among university officials and activity within European universities and research institutes has increased significantly.
Clarysse, Tartari, and Salter (2011)	The TTO's role in increasing entrepreneurial activities of academics appears to be limited. TTOs spend most of their time protecting technology and formalizing the contractual relations around it.
Coupe (2003)	A university with a TTO will have a higher expected number of patents than the university without a TTO, and the effect of the TTO increases over time.

Friedman and Silberman (2003)	Almost all universities have established TTOs to foster interaction with industry and commercialization of research. After an invention is conveyed to the TTO, it is responsible for patenting it.
Henderson, Jaffe, and Trajtenberg (1998)	Federal policies, like the Bayh-Dole Act, created an impetus toward more commercial research, leading to an increase in universities' institutional commitment to patenting in the form of new and expanded TTOs and licensing offices.
Jensen, Thursby, and Thursby (2003)	TTOs have primary responsibility for the university licensing function and implementing provisions of the Bayh Dole Act. TTOs are responsible for facilitating faculty disclosure of inventions, evaluating those inventions disclosed, as well as finding licensees and executing contracts on behalf of the central administration for the university.
Litan, Mitchell, and Reedy (2007)	Faculty must notify the TTO of their discoveries and delegate to the university all rights to negotiate licenses on their behalf.
Mitchell (1991)	On-site technology patent and license offices can increase information flow out of their institution so that potential commercializers are more likely to learn of the product, and obtain patents so as to increase the likelihood that a company will invest in further refinement of the technology. The office acts as a liaison between the researcher and the manufacturer.
O'Shea, Allen, Chevalier, and Roche (2005)	The TTO plays a key role in engendering academic entrepreneurship by engineering synergistic networks between academics and venture capitalists, advisors, and managers who provide the human and financial resources necessary to start a company; and by providing company formation expertise (many TTO personnel have experience in evaluating markets, writing business plans, raising venture capital, obtaining space and equipment, etc.).
Siegel, Waldman, Atwater, and Link (2004)	The role of the TTO is to facilitate commercial knowledge transfers through the licensing to industry of inventions or other forms of intellectual property resulting from university research. The TTO must understand the field and evaluate where its technology is moving in order to decide whether or not a patent should be filed on the discovery.
Siegel, Waldman, and Link (2003)	Once the invention is formally disclosed, the TTO simultaneously evaluates the commercial potential of the technology and decides whether to patent the innovation.

Literature Related to the TTO's Evaluation of Technology to be Patented

Process 3 in Figure 1 primarily involves how the TTO evaluates an invention. The literature summarized in Table 3 provides an overview of the general criteria most TTOs seem to employ when evaluating the viability of an invention. Inventions that receive positive evaluations are typically believed to be commercially viable, potentially competitive in the market place, and profitable for the university. Measuring faculty quality is also a method used to capture patent potential; discoveries by star scientists with successful track records are more likely to be invested in by the TTO in the hopes of the technology being developed into a prestigious, lucrative product.

Process 3 also involves all of the initial background work done by the TTO to begin the patent application process. This includes researching patent costs, conducting patent searches, and considering university preferences regarding different types of patents.

Table 3
Literature Related to the TTO's Evaluation of Technology to be Patented

Author(s)	**Key Findings**
Goldhor and Lund (1983)	Technology that is ideal for transfer is revolutionary, extensible, ripe, defensible, portable, and has broad commercialization potential. If the invention meets these criteria, it is more likely to be picked up by the university's patent office.
Jensen and Thursby (2001)	Most universities now make patenting decisions that explicitly consider the salability of university inventions, and apply for patents conditional on the identification of a potential licensee for the technology.
Litan, Mitchell, and Reedy (2007)	Many TTOs focus their limited time and resources on the technologies that appear to promise the biggest, fastest payback.
Rosenberg, and Nelson (1994)	Commercially-oriented university activity, like patenting and licensing, has been important to the growth of the computer science, biotechnology, semiconductor, and chemical/electrical/ mechanical industries.
Shane (2004b)	Patenting imposes a cost that, from an economic perspective, is worth incurring only if the royalties from licensing those patents exceed the average cost of patenting.
Siegel, Waldman, Atwater, and Link (2004)	Global patent protection is the most expensive type of patent, so universities might choose to apply for a domestic patent that protects the technology at a significantly lower cost.

Siegel, Waldman, and Link (2003)	The TTO must consider the commercial potential of the invention, as well as prospective interest from industry.
Thursby, Jensen, and Thursby (2001)	The most important objective to the TTO is royalties and fees generated. Certain fields that are more likely to have invention disclosures are medicine, engineering, and science.
Thursby and Thursby (2002)	The TTO applies for patents on the disclosures they believe can be patented and licensed. Inputs for this stage include a measure of faculty quality to capture patent potential.
Thursby and Kemp (2002)	Biological sciences and engineering are more important to licensing activity than are the physical sciences. This observation can be attributed to the more applied nature of engineering and the better market opportunities and orientation toward markets of biological sciences.

Literature Related to Acquiring Patents

Process 4 details the methods of moving from submitting patent applications to the patent being awarded, and from acquiring a patent to preparing to market the technology to firms and entrepreneurs. The major hurdle in this process that can make or break the flow of a technology is whether or not the patent application is accepted and the patent awarded. As noted earlier, the time it takes to acquire a patent can be lengthy; patience is a virtue for the TTO, as the duration of this process can easily span two or more years.

The primary method used to move from the patent application stage to the marketing stage is adequate involvement and effort by the TTO. It is the TTO's responsibility to file patent applications with the USPTO on behalf of the university. The TTO must also establish an ideal end goal for the development and commercialization of the technology in order to plan how to effectively market the embryonic technology to firms and entrepreneurs. Table 4 summarizes the literature on patent acquisitions by universities.

Table 4
Literature Related to Acquiring Patents

Author(s)	**Key Findings**
Bercovitz, Feldman, Feller, and Burton (2001)	All U.S. universities have acquired broader IP rights since 1980, but considerable diversity exists in technology transfer procedures and policies as well as the organization of TTOs and IP offices developed in response to legislation and market opportunities.

Carlsson and Fridh (2002)	The annual budget for licensing and patenting activities within the TTO ranges from $320,000 to over $2 million. Universities can actively facilitate patenting, but always within the constraints set by the budget (the patenting cost is typically in the $15,000 – $20,000 range per application).
Colyvas, Crow, Gelijns, Mazzoleni, Nelson, Rosenberg, and Sampat (2002)	Since the passage of the Bayh-Dole Act, there has been a dramatic increase in patenting and licensing by universities and the number of universities with TTOs. There are reasons to doubt that patents and patent licensing are any more necessary for effective transfer today than in earlier years. The principal effect of Bayh-Dole was to accelerate and magnify trends that already were occurring.
Kim (2011)	Most universities traditionally assigned a low value to patenting and licensing because both required high fixed costs compared to the benefits they conferred. The U.S. patent system has been reconfigured to stimulate productive knowledge diffusion and thus enhance the economic value of academic research.
Markman, Gianiodis, Phan, and Balkin (2005)	The faster TTOs can commercialize patent-protected technologies, the greater their licensing revenue streams and the more new ventures they can potentially spin off. Speed is determined by TTO resources and structure, their competency in identifying licensees, and participation of faculty inventors in the licensing process.
Mitchell (1991)	Because prosecuting a patent is relatively expensive, a licensing office cannot file for patent protection on every item that is disclosed to it. Thus, it must make commercial judgments. In addition, it must decide whether to file only in the United States or to incur the additional expense of obtaining foreign patent protection.
Shane (2004b)	Universities active in patenting and licensing before the Bayh-Dole Act responded to the Act by creating or revamping their IP policies, establishing or reorganizing their TTOs, and transferring the responsibility for making patenting decisions to TTOs. Consequently, in the post-Bayh-Dole era technology-licensing officers make patenting decisions.
Siegel, Waldman, and Link (2003)	Domestic patent protection is substantially cheaper than global, but often much less valuable to potential licensees, particularly when foreign markets are perceived to be highly lucrative relative to the U.S. market. This is a dilemma for many TTOs because they have limited resources for filing patents.
Siegel, Waldman, Atwater, and	Universities have limited budgets for filing patents. Global

Link (2004)	patent protection is quite expensive, so universities might choose to apply for domestic patent protection, which safeguards the technology at a much lower cost.
Siegel and Phan (2005)	Given the high cost of filing and protecting patents, some institutions are reluctant to file for a patent if there is little interest expressed by industry in the technology.

Literature Related to the Role of the Technology Transfer Agent and Marketing Technology to Firms

Moving from the TTO marketing the technology to negotiating the licensing agreement is Process 5. It revolves around interactions between the TTO and firms. The principal methods used to progress through this step are marketing techniques and establishing or building mutually beneficial relationships between universities and firms. For this process to be successful, the TTO must have successfully marketed the technology, narrowed the potential firms with which to do business, and begun building a relationship with the firm that can best develop the technology.

Process 5 is perhaps the stage where the technology transfer agent is most important. The technology transfer agent facilitates the process by acting as a mediator between the university and industry. Because the goals, objectives and operations of universities and firms in industry are often quite different, the technology transfer agent bridges the gap between academics and firms to ensure the process is as efficient as possible. Table 5 summarizes the literature on marketing techniques employed by TTOs, the importance of connections between universities and industry, and the role of the technology transfer agent.

Table 5
Literature Related to the Role of the Technology Transfer Agent and Marketing Technology to Firms

Author(s)	**Key Findings**
Colyvas, Crow, Gelijns, Mazzoleni, Nelson, Rosenberg, and Sampat (2002)	The TTO's marketing activities are most important for inventions in technological areas where existing links between academia and industry are weak.
Goldhor and Lund (1983)	The technology transfer agent is the keystone of the technology transfer process. The technology transfer agent can help match the capabilities of the source technology with the requirements of the envisioned target technology, provide

	technical expertise and consulting, and act as a 'translator' between the donor and recipient.
Etzkowitz (2003a)	The creation of an infrastructure at universities to transfer technology is significant not only for the incorporation of a marketing arm in the university but also for its ability to enhance the marketability of academic knowledge. The collectivity of TTOs of universities and firms creates a technology market.
Markman,Gianiodis, Phan, and Balkin (2005)	The faster TTOs can commercialize patent-protected technologies, the greater their licensing royalties and the more new ventures they spin off. Speed is determined by TTO resources, their competency in identifying licensees, and participation of faculty inventors in the licensing process.
Mitchell (1991)	A major part of technology transfer is information dissemination- linking commercializable products with capable manufacturers. The TTO can help match an established firm with a new product that ties in well with their existing capabilities, but that is outside its existing market and may not have been seen by the firm otherwise. Licensing offices must publicize their holdings and licensing personnel must establish networks of trade contacts.
Siegel and Phan (2005)	If a patent is granted, the university typically attempts to market the invention by contacting firms that can potentially license the technology or entrepreneurs who are capable of launching a startup firm based on the technology. This role highlights the importance of the technology licensing officer's personal networks and their knowledge of potential users of the technology.
Siegel, Waldman, Atwater, and Link (2004)	It is proposed that universities that allocate more resources to the TTO will devote more effort to marketing technologies to firms. A large TTO staff is often required to market technologies effectively, especially when the reputation of the university is not sufficient to draw unsolicited attention to their patent portfolio. Non-top-tier institutions must be more proactive in marketing.
Thursby, Jensen, and Thursby (2001)	Procedures for marketing technology include, by descending prevalence: interactions/relationships with personal contacts of the TTO, relationships with inventor contacts, direct mailing/fax communications, websites, meetings, and trade shows.

Literature Related to Licensing

Process 6 involves progression from negotiations to licensing. This process establishes the official working relationship between the university and industry. Within this process, the literature describes the different types and elements of licenses, and what each party desires in a licensing agreement. This process often requires compromise on the terms and conditions of the license between the university and firm.

Table 6
Literature Related to Licensing

Author(s)	**Key Findings**
Bray and Lee (2000)	Licensing managers have begun to take equity in startup companies in combination with, or in place of, license issue fees or royalties. The average value of equity is several times higher than the average annual income from a license. When combined with a strong program of traditional licensing, taking equity in startup companies maximizes the financial return universities realize from their IP.
Carlsson and Fridh (2002)	Research expenditures, number of invention disclosures, and age of the TTO have a positive impact on university patenting and licensing.
Friedman and Silberman (2003)	Some universities take equity positions rather than license income from an executed license agreement. Income to the inventor, experience of the TTO, a focused mission supporting licensing and royalty income and the technology industry environment of the university all influence the number of licenses executed. Typically, there is a three to seven year lag from the time a license agreement is signed until it begins to generate income.
Jensen and Thursby (2001)	Development of inventions would not occur unless the inventor's return is tied to the licensee's output when the invention is successful. Most licensing agreements include royalty payments, although technology managers are increasingly including equity participation.
Markman, Phan, Balkin, and Gianiodis (2005)	Licensing-for-equity strategy is positively related to new venture formation, while sponsored-research-licensing strategy is negatively related. Licensing-for-cash strategy, the most prevalent transfer strategy, is infrequently correlated with new venture formation.
Shane (2002)	Technology licensing by entrepreneurial firms depends on mechanisms to provide financing, lower royalty payments, and capitalize patent costs in the form of equity investments.

	Technology licensing depends on licensing office expertise in firm creation, licensees with strong intellectual property protection, and access to technology families. Entrepreneurial firms license different types of technology and license inventions from different inventors than do large firms.
Shane (2004a)	The effectiveness of licensing in a line of business is significantly correlated with university share of patents in the post-Bayh-Dole period, but not in the pre-Bayh-Dole period. Licensing is not equally effective across all technologies, so the incentive to become more commercially focused has led universities to concentrate patenting in fields in which knowledge is transferred effectively through licensing.
Siegel, Waldman, Atwater, and Link (2004)	When negotiating a licensing agreement, firms appear to place greater emphasis on factors that do not necessarily generate additional revenue for the university (such as informal transfer of know-how and product development), while university administrators appear to be focused on dimensions that generate additional research income. TTOs may be overly focused on the legal aspects of licensing.
Siegel and Phan (2005)	Licensing agreements entail either upfront royalties, royalties at a later date, or equity in a startup firm launched to commercialize the technology.
Siegel, Waldman, and Link (2003)	Licensing agreements are characterized by constant returns to scale with increasing returns for licensing revenue.
Sine, Shane, and Di Gregorio (2003)	Institutional prestige influences the number of licenses that a university annually generates over and above the rate that is explained by the university's past licensing performance.
Thursby, Jensen, and Thursby (2001)	Inventor involvement is important for finding licensees and further development once licenses are executed. Almost half of the licensed inventions are only a proof of concept at the time of the license. Licenses executed include payment schemes that induce inventor involvement in development and do not obligate the licensees to large up-front payments.
Thursby and Kemp (2002)	The importance of licenses executed follows from its central role in the commercialization process. Number of licenses executed has the greatest impact on efficiency (the relative productivity of universities in licensing their IP).

Literature Related to Adaptation and Use of Transferred Technology

Technology is transferred as firms adapt and use licensed technology. A persistent theme in the literature is that disclosed inventions are embryonic in nature and thus typically require extensive development before they are ready to be introduced to the market.

The ongoing involvement of the university scientist is especially crucial in this final process. Without input and contributions from the university scientist who made the discovery, Process 7 is unlikely to be completed successfully. The university scientist generally has the greatest understanding of their invention and its potential, and can be indispensable in making sure that the technology is licensed to the most commercially-capable firm, and in directing the invention towards successful and profitable development.

Table 7
Literature Related to Adaptation and Use of Transferred Technology

Author(s)	**Key Findings**
Colyvas, Crow, Gelijns, Mazzoleni, Nelson, Rosenberg, and Sampat (2002)	An implicit assumption underlying the Bayh-Dole Act is that, for the most part, university research results of potential use in industry are embryonic inventions requiring follow-on research and development by industry.
Goldhor and Lund (1983)	A large gap remains between laboratory demonstrations and commercial utilization. Transferring the source technology is a sequential process involving steps of adaptation and utilization that may change the technology into something quite different from that issuing from the source.
Hayter (2011)	All entrepreneurs have license agreements with their home university, but most have yet to commercialize their technologies. In most cases, the technology requires extensive development. Because a technology has been licensed to a company—including a spinoff—does not signify penetration of the knowledge filter. While the IP is no longer owned by the university, it remains embedded in the individual faculty entrepreneur until it is commercialized.
Jensen and Thursby (2001)	When licensed, most university inventions are little more than a proof of concept and are embryonic, so additional effort in development by the inventor is required for a reasonable chance of commercial success.
Mitchell (1991)	Because research designs are usually far from commercially ready, additional resources for research and development are needed to bring them to market. The additional effort often must draw on tacit knowledge held by the developer, so ongoing contact between the research sites and manufacturing personnel is usually necessary.
Mowery, Nelson, Sampat, and Ziedonis (2001)	The areas in which university research has grown rapidly have been rich in results with commercial promise, but much of the research that generated them has been quite

	fundamental in nature.
Rasmussen and Sorheim (2012)	University spinoffs often develop early-stage technologies characterized by long development paths and uncertain commercial potential.
Thursby, Jensen, and Thursby (2001)	The majority of inventions are at an early stage of development when they are licensed. Inventor involvement in the process is important for finding licensees and for further development once licenses are executed. Specialized faculty knowledge and involvement is necessary for firms to be willing to license and develop early stage technologies.

Literature Related to Spinoff and Startup Creation

Table 8 summarizes the literature regarding spinoff and startup creation within the traditional technology transfer model. Process 8 involves the technology transfer process from licensing to the creation of a spinoff or startup company. This process can occur in two directions based on the parties that enter the licensing agreement with the university. These parties might include a member of a university science/research park, the inventing faculty member, an entrepreneur, etc. The methods employed in this process depend on the type of technology and the intentions for the technology. For instance, certain types of technology may be better suited to be exploited within university science/research parks, while others may develop more successfully with the freedom of an independent startup.

Table 8
Spinoff and Startup Creation

Author(s)	**Key Findings**
Baycan and Stough (2012b)	Spinoffs are an effective commercialization vehicle for uncertain technologies and an effective vehicle for encouraging investor involvement.
Carayannis, Rogers, Kurihara, and Allbritton (1998)	Four primary roles that are usually involved in the spinoff process are: the technology originator, the entrepreneur, the parent organization, and the venture investor. Two economic elements are almost always involved in each spinoff: an entrepreneur who usually transfers from a parent organization and a technology on which the new venture is based.
Carlsson and Fridh (2002)	The university’s policies are not the only determinant of spinoffs and their degree of success; the history, culture, attitudes, industry affiliation, market orientation, etc., of

	existing businesses, and the presence or absence of venture capital, as well as the vigor and diversity of supporting organizations and institutions are also important.
Clarysse and Moray (2004)	The spinoff process encompasses an idea phase, a pre-start phase, a startup phase, and a post-startup phase. The development of the champion role and the entrepreneurial team as a whole interrelates with life cycle stages of the venture and, if successful, can increase the likelihood of survival of the startup.
Clarysse, Wright, Lockett, Van de Velde, and Vohora (2005)	Three models of managing the spinout process are: Low Selective (mainly concerned with creating as many startups as possible), Supportive (originates from general idea of commercializing technology through means other than licensing), and Incubator (fosters circumstances under which spinouts can become more financially attractive than licensing or contract research with established industry).
Di Gregorio and Shane (2003)	The two key determinants of startups are faculty quality and the ability of the university and inventor(s) to assume equity in a startup in lieu of licensing fees.
Druilhe and Garnsey (2004)	Diversity of spinouts, that is the type and intensity of resources academic entrepreneurs require for realizing a business opportunity, are likely to vary considerably according to the type of activity undertaken and the amount of resources already possessed by the entrepreneur (e.g., prior knowledge, contacts, and experience).
Fontes (2005)	Spinoff entrepreneurs play a valuable agency role in the access, application and dissemination of knowledge originating from research organizations. Spinoffs can directly bring new technologies, products, and processes to the market; all of these dimensions represent an application of knowledge produced in research organizations and assist existing companies in the development of new technologies. Spinoffs have emerged as an alternative to technology transfer organizations and mechanisms.
Grandi and Grimaldi (2005)	The market attractiveness of a business idea at the time of founding is positively influenced by the market orientation of the academic startup’s founders and by their frequency of interaction with external agents. The business idea articulation at the time of founding is positively affected by the degree of prior joint experience and by the articulation of roles within the academic startup founders.
Harmon Ardishvili, Cardozo, Elder, Leuthold, and Parshall (1997)	A new company might be created specifically to sell the technology invented in the university’s laboratory.

Hayter (2011)	Not all spinoffs are formed for the purpose of maximizing profit. Academic entrepreneurs establish companies for various reasons, including technology development, personal financial gain, public service, career enrichment, job creation, and skill enhancement. Entrepreneurial motivations are also related to the influence of peers, and spinoffs can act as a platform for consulting and access to government grants, especially SBIR awards.
Leitch and Harrison (2005)	The TTO may play an ongoing role in second-order spinouts (companies formed on technology developed in a spinout company with no connection to the university) by supporting their development and taking equity stakes in them. The original parent/incubator organization can continue to play a role in channeling resources into startup ventures and providing legitimacy and credibility.
Link and Scott (2005)	University spinoffs are more likely to originate in science/research parks that are geographically close to the university. This spacial relationship is notable in in parks that emphasize biotechnology.
Lockett and Wright (2005)	The number of spinout companies created and the number of spinout companies created with equity investment are positively associated with university expenditure on IP protection, the business development capabilities of TTOs, and the royalty regime of the university.
Markman, Phan, Balkin, and Gianiodis (2004)	Monetary incentives given to scientists whose inventions were successfully licensed are negatively related to the number of equity licenses in young ventures and to the number of startups.
Nerkar and Shane (2003)	Overall, new technology firms are less likely to fail if they exploit radical technology and have broad scope patents that are contingent on the industry environment.
O’Shea, Allen, Chevalier, and Roche (2005)	Previous success in technology transfer, high faculty quality, science and engineering funding base with an orientation in life science, chemistry, and computer science disciplines, industry funding, and a strong commercial resource base are all positively related to university spinoff generation.
Powers and McDougall (2005)	The level of industry R&D funding, faculty quality, the age of the TTO, and the level of venture capital investment in a university’s metropolitan statistical area are positive predictors of two measures of technology transfer performance: the number of startup companies formed and the number of newly public companies to which a university had previously licensed a technology.
Siegel and Phan (2005)	The benefits of concluding the technology transfer process

	with a spinoff or startup company include the potential for the spinoff or startup to generate a long-term payoff, create jobs, and generate high returns if the firm is taken public.
Steffensen, Rogers, and Speakman (2000)	Factors important to success of a spinoff company include the degree of support it receives from the university. Obstacles to success include time-consuming negotiations of IP rights and competition between the spinoff and university for scarce resources.
Wright, Clarysse, Mustar, and Lockett (2007)	Framework conditions necessary to facilitate startup creation include determination of the ownership of IP; availability of venture capital funds; creation of the possibility and the capabilities for academics to create a company; support for the project; and development of TTOs, incubators, and seed capital funds in or around universities and/or public research institutions. Different types of spinoffs include venture capital-backed, prospector, and lifestyle type spinoffs.
Wright, Mosey, and Noke (2011)	Some scientists pursue academic entrepreneurship indirectly by leaving universities to work for corporations before they start their ventures. Corporate spinoffs on average are better performers than university spinoffs, demonstrating the spillover impact of university knowledge.
Vohora, Wright, and Lockett (2004)	University spinouts develop in a non-linear fashion over five distinct phases: research, opportunity framing, pre-organization, re-orientation stage, and sustainable returns. At the transition between phases there are four critical junctures in terms of the resources and capabilities for the next phase: opportunity recognition, entrepreneurial commitment, credibility, and sustainability.

4. Limitations of the Traditional Model

Although characteristic of the path to market for some innovations, the traditional model in Figure 1 has a number of limitations. Simply, the traditional model documented in the extant literature does not accurately capture the complexities of technology transfer in practice. In this chapter the weaknesses and misrepresentations in the way that the literature characterizes the technology transfer process is discussed. Then, in Chapter 5 an alternative model is posited that is a more realistic characterization of the practice of technology transfer.

The limitations of the traditional model of technology transfer fall into the following categories and subcategories:

- Inaccuracies
    - Strict linearity and oversimplification
    - Composition
    - One-size-fits-all
    - Overemphasis on patents
- Inadequacies
    - Formal vs. informal mechanisms
    - Organizational culture
    - Reward systems

The inaccuracies in the traditional model relate to discrepancies between academic postulations and how technology transfer is practiced in universities. The traditional model binds technology transfer to a rigid linear path, and it oversimplifies the underlying, and often subtle, complexities of the process. The composition of the traditional model requires rearrangement and reorganization in order to capture the various branches of a practiced technology transfer process. A one-size-fits-all traditional model does not accurately depict differences in technology transfer across disciplines, and forcing all disclosures to follow the traditional linear model's path to commercialization will likely ensure that many inventions fail in the transfer process. Finally, the traditional model places too much emphasis on the importance of patents as the primary output in the technology transfer process, thus overlooking other mechanisms for profitability and commercialization.

The inadequacies in the traditional model relate to processes that it fails to address. The traditional linear model fails to acknowledge the importance of informal mechanisms of technology transfer. The organizational cultures of the university and of the firm impact the majority of the technology transfer process, but these elements are not acknowledged or addressed in the traditional model. The types of reward systems in place in universities can greatly facilitate or impede faculty involvement in technology transfer activities, yet the traditional model has no representation of their influence.

Inaccuracies

Strict Linearity and Oversimplification

One limitation of the traditional model is its linear representation of the processes involved in technology transfer. Through in-depth interviews and discussions with technology transfer practitioners, it became clear that the actual technology transfer process in practice is non-linear.[6] The processes included in the traditional model are undoubtedly important components of the overall technology transfer process; however, the traditional model does not capture the various paths to commercialization an innovation can take, and it is neither complex nor comprehensive enough to describe reality.

All models necessarily simplify reality for the sake of clarity and graphical representation. Models are thus a useful tool for condensing matters to achieve widespread, general understanding of complex situations. However, the traditional model in Figure 1 fails to capture technology transfer as it is now practiced, and it is not particularly useful for understanding the routes to commercialization available to universities. A linear model of the technology transfer process does not fully take into account external environmental factors, such as market demand or regulatory changes that can influence the technological innovation process (Rogers, Takegami, and Yin, 2001). Further, as the interviews revealed, the technology transfer process is in practice context dependent.

For example, a model that accurately, albeit simply, depicts the technology transfer process for an invention in nanotechnology may be completely inapplicable to an invention in software or energy. As such, other representations of university technology transfer are needed that are

[6] Analysis of the limitations of the traditional model is supported by a series of informal interviews with experienced technology transfer practitioners and academic and industry contacts, conducted throughout this study.

not only general enough to act as a starting point for universities engaged in applied research but also specific enough that various versions can be adapted to the wide range of technology disciplines and institutional settings. In other words, multiple representations can and should proliferate.

An underlying assumption of the linear model as discussed in the academic and professional literatures is that the research in question is typically federally-funded and conducted by a university faculty member. The traditional model fails to consider alternative sources of funding and sources of discoveries. For instance, in addition to federal contracts or grants, there is a burgeoning trend of corporate contracts with, for example, university research centers. Donations can also be an important component of research funding. It is important to note that the source of funding could, and often will, have an impact on the path to market of the innovation, thus introducing variability to the technology transfer process and emphasizing the limitations of depicting technology transfer within a linear framework.

The linear model oversimplifies the discovery process by attributing it to only university scientists. Discoveries are rarely made in isolation by one individual and decisions to disclose likely involve input from various perspectives. Alternative sources of discoveries can include disclosures from research staff, graduate students, and even undergraduates. Perhaps a better representation would depict the importance of research teams, university-industry contacts, and other cooperative efforts.

The following discussion emphasizes assumptions within the traditional model that have evolved over time to become incorrect or inapplicable as university technology transfer efforts have matured and underscores the fact that the traditional model is overly simplistic.

Composition

The placement of some of the components within the linear configuration is another limitation of the traditional model. For example, through interviews with university technology transfer practitioners, it was learned that the marketing process can and frequently does begin before the TTO pursues a patent. Simply, the TTO wants to gauge industry interest before putting substantial time and resources into developing an invention. Also, creating spinoffs and startups could occur earlier in the process than shown in the traditional model, especially if the university scientist or TTO intends to immediately establish a spinoff or startup. To create a more accurate representation of technology transfer in practice, some of the components and connections should be rearranged.

Codified in 35 U.S.C. 206, the Bayh-Dole Act requires the Secretary of Commerce to produce standard patent rights clauses. Section 37 C.F.R. 401.14, the Standard Patent Rights Clause (SPRC), is the contractual means by which federal agencies manage patent rights in funding agreements.[7] Under Sub-Section (f)(2) of the SPRC, the university requires a written agreement from its research employees to protect the federal government's interests. When research is conducted by a university scientist and an invention is made, under the SPRC, the university may: elect to retain title, assign its interest under the SPRC, or decline to retain title.

If the university retains title, it can prevent the federal funding agency from requesting title from the university's scientist. Essentially, the university stands in for the federal agency to undertake the objectives of using patenting to promote the utilization of federally funded inventions under Bayh-Dole.

If the university declines to retain title, the federal agency may: request title under (f)(2) and file patent applications, request title under (f)(2) and let invention enter public domain, or allow the inventors to retain title, subject to 27 CFR 401.9 (after consulting with university).

Kenney and Patton (2009) build on these options to present two alternative invention commercialization models. The first is to vest ownership with the inventor, who could choose the commercialization path for the invention, and the inventor would provide the university with an ownership stake in any returns. The inventor could contract with the TTO or an outside entity to commercialize their invention. The second model is to make all university inventions immediately available to the public, either through the public domain or non-exclusive licensing. These alternatives fit within the parameters of the Bayh-Dole Act while encouraging economic efficiency and entrepreneurship.

The intricacies of the Bayh-Dole Act are important for developing other, more representative heuristics. Whether the university elects to retain title and how the federal agency responds can decide the path to market an invention follows, so it is essential to capture each potential branch-off in the composition of other versions.

[7]This examination of the Standard Patent Rights Clause and the Bayh-Dole Act as it applies to models of university technology transfer is aided by a series of conversations with, and writings of Barnett (2010, 2011).

One-Size-Fits-All

The Bayh-Dole Act was implicitly based on an assumption of a linear model of innovation in which patent-based incentives link universities, inventors, and industry in the commercialization process (Mowery, 2009). This underlying assumption ties back to which universities were the big players in technology transfer prior to the Bayh-Dole Act—a small number of elite universities, such as MIT, Stanford University, and the University of California system are recognized as forerunners in conducting patenting and licensing activities (Bercovitz and Feldman, 2006; Goldstein, Bergman, and Maier, 2012). These institutions served as role models for universities seeking to increase their patenting and licensing activities, and most of the innovations developed by these elite universities were within scientific disciplines. Also, during the period immediately surrounding the passage of the Bayh-Dole Act, technological advances in biomedical areas, molecular biology, computer technology, and other sciences became increasingly prominent in university research (Colyvas, Crow, Gelijns, Mazzoleni, Nelson, Rosenberg, and Sampat, 2002; Geuna and Nesta, 2006). For example, Shane (2004a) finds that the majority of MIT spinoff companies from 1980 to 1996 were within the biomedical industry. Golub's (2003) research finds that half of the spinoffs from Columbia University were in the biomedical industry, with the other half in the electronics and software fields. Dueker (1997) argues that biomedical inventions were the genesis of university technology transfer and have played a critical role in the development of modern university licensing practices. Unsurprisingly, the traditional linear model of technology transfer as based on the literature is most representative of 'homerun' innovations in biotechnology and similar fields.

Also, the Bayh-Dole Act was intended to facilitate commercialization by making it easier for universities to claim legal rights to innovations developed by their faculty using federal funding, but these new rights are accompanied by red tape and bureaucracy (Litan, Mitchell, and Reedy, 2007). Litan, Mitchell, and Reedy (2007) describe how university administrative issues, such as an overemphasis on maximizing revenues from licensing, have caused TTOs to become bottlenecks. The most effective course of action would be for universities to implement broad innovation and commercialization strategies that recognize different pathways to commercialization, and programs and initiatives to support each path. However, attempts to streamline and maximize innovation-dissemination activities have resulted in universities channeling most, if not all, technology development through the TTO. Such an inflow of unfiltered ideas might not allow innovations to be disseminated effectively; hence, the TTO becomes a bottleneck. This potential bottleneck is due largely to the incorrect assumption that the technology transfer process is the same for all innovations and as such, all innovations should be treated the same on their path to market.

As universities have matured in their transfer efforts it is becoming apparent that the technology transfer process varies greatly across fields (Genet, Errabi, and Gauthier, 2012; Mowery, 2009). For example, Mowery (2009) summarizes several studies examining the influence of university research on industrial innovation (Levin et al., 1987; Cohen et al., 2002) which indicate, for example, that the relationship between academic research and industrial innovation in the biomedical field differs from that in other knowledge-intensive sectors. These studies emphasize that there is considerable heterogeneity among inventions in the role of IP rights thus influencing how firms develop and commercialize university inventions, in the role of the inventor in continued development and commercialization after licensing, and in the relationship between academic-industry research activities across technical fields.

Disclosure of innovations in non-traditional fields is increasing in universities across the United States. For example, recent creative-works innovations at the University of North Carolina at Greensboro include a peer education program, a wireless lighting and communication device, and an educational pedagogy (Goble, 2012). Brigham Young University has established a Creative Works Office to facilitate non-traditional technology transfer, with innovations as varied as language software and relationship assessment programs (Tata, 2012). As universities look to diversify their technology transfer activities across disciplines and research fields, it is increasingly evident that the traditional linear model is insufficient in its applicability. An alternative model must account for diversity in the technology transfer process, with the understanding that modeling effective methods of technology transfer is not one-size-fits all.

Overemphasis on Patents

Another critique of the traditional model is that it overstates the role of patents in the technology transfer process. Patents can be an important intermediate output and tool in bringing a new invention to market, but there is a shift occurring in how TTOs choose to protect their inventions. Patenting is one strategy towards achieving successful technology transfer, but it should not be an end unto itself. That is, patents are one of many options to be considered in practice for IP protection. Other IP protections such as trademarks and copyrights are becoming more prevalent at universities. Geuna and Muscio (2009) note that only a small fraction of the research conducted at universities can be codified through patents, and the patent-centered technology transfer process accounts for only a small portion of the overall knowledge transferred to industry. When university administrators put too much emphasis on patenting and licensing for its own sake, the operation of other effective channels through which university inventions reach commercial application might be compromised or even overlooked (Mowery, Nelson, Sampat, and Ziedonis, 2001).

Relatedly, the academic literature has become critical about using the number of patents acquired by universities as a measure of technology transfer success. Patent-based statistics may be a misleading indicator of a university's technological productivity because many inventions are developed at one university but patented at another institution (Saragossi and van Pottelsberghe de la Potterie, 2003). Henderson, Jaffe, and Trajtenberg (1998) analyze patent data from 1965 to 1991 and conclude that the relative importance and generality of university patents has fallen at the same time as the sheer number of university patents has increased. These authors find that this trend is largely the result of a very rapid increase in the number of low-quality patents being granted to universities. Hicks, Breitzman, Olivastro, and Hamilton (2001) agree that steady growth in university patenting has been accompanied by a steady fall in the average quality of university patents.

Also, the rapid rise of academic patenting in the late 20th century was driven largely by the growing technological opportunities in the biomedical sciences and the feasibility of pursuing those opportunities in university laboratories (Geuna and Nesta, 2006). The boom in patenting after the passage of the Bayh-Dole Act reflects increased patent activities by universities with considerable pre-1980 patenting and licensing experience, as well as entry into patent activities by universities with little to no experience. The escalation in patent activities by inexperienced universities seems to have negatively affected quality of university patenting (Mowery, 2009).

The exaggerated importance of patents in the traditional model reflects an overemphasis on quantity, or number of patents, in place of quality, wherein patents are only pursued for inventions which would most benefit from them on their path to market. Therefore, measuring university technology transfer success solely by licensing or patenting activities masks the importance of other means of knowledge diffusion, including non-patent innovations, spinoff and startup companies, and university-industry consulting (Litan, Mitchell, and Reedy, 2007).

Inadequacies

Formal vs. Informal Mechanisms

The linear and inflexible technology transfer process reflected in the traditional model restricts inventions to following one particular path, and often ignores those that do not or cannot follow this model. Siegel, Waldman, Atwater, and Link (2004) suggest that the traditional model understates the complexity of the technology transfer process, and they propose that when university inflexibility is high, university scientists will circumvent formal technology transfer processes and rely more heavily on informal commercialization and knowledge transfer. These authors conclude that universities that become involved in formal and informal UTT will experience an increase in basic research activity. Link, Siegel, and Bozeman (2007) define informal technology transfer mechanisms as facilitating the flow of technological knowledge through informal communication processes. Grimpe and Fier (2010) describe formal technology transfer as a mechanism to allocate property rights, whereas informal technology transfer is more about informal communication processes.

Informal technology transfer mechanisms include communication processes, such as consulting and collaborative research; interactions between faculty members and industry contacts; joint publications; and informal knowledge transfer between the university and the firm. These informal contacts and knowledge exchanges are more difficult to quantify than formal mechanisms, but are important to acknowledge and are often a catalyst for instigating further formal contacts (Debackere and Veugelers, 2005). Kenney and Patton (2009) and Kumar (2010) refer to the “gray market” of technology transfer, wherein researchers bypass the TTO and instead utilize their links to industrial researchers or postdoctoral students. Bercovitz and Feldman (2006) note that research on technology transfer practices tends to analyze formal mechanisms including sponsored research agreements, licenses, or equity swaps; but, they argue that this focus is too narrow. In reality, firm-industry interactions combine both formal and informal exchanges and are influenced by firm strategy, industry characteristics, university policies, and the structure of technology transfer operations within governmental policy parameters (Bercovitz and Feldman, 2006). Informal technology transfer mechanisms are an important contribution to the technology transfer process and as such should be taken into account when offering alternative views.

Organizational Culture

The technology transfer process from discovery to commercialization is also affected by the organizational culture of the university. The setting in which an innovation is developed influences how the technology transfer process occurs in practice. The overall innovative culture and environment of the university is a somewhat intangible component, but the literature documents that the environment can have a significant impact on many of the processes shown in the traditional model. For example, the organizational culture of the university scientist might place great emphasis on dimensions of prestige—being recognized within the scientific community, being granted tenure, being published, being awarded research grants, etc. The traditional academic career trajectory encourages and rewards the production of new scientific knowledge, making university scientists surrounded by such culture less likely to commercialize their knowledge (Baycan and Stough, 2012b; Göktepe-Hulten and Mahagaonkar, 2010).

The firm's organizational culture is also important. Typically, industry is more entrepreneurial and profit-oriented than university environments. While academic culture traditionally centers on production of knowledge and scientific excellence, business culture centers on valorization of knowledge (Baycan and Stough, 2012b). These differences are important, and recognizing them and dealing with them is a critical challenge to the TTO, albeit one that is not seen in the traditional model. The TTO can be instrumental in reducing asymmetric information between university and industry that is typically encountered in the scientific knowledge market (Debackere and Veugelers, 2005).

There is also a disconnect between the sub-cultures of university scientists and the university administrators (Siegel, Waldman, Atwater, and Link, 2004). An academic department's culture that is supportive to entrepreneurial activity could help counteract disincentives created by a university environment that is not supportive of entrepreneurial activities (Kenney and Goe, 2004). The discipline in which a university scientist operates, viewed as a form of organization and community, may be more important than their university's overall entrepreneurial climate in influencing faculty attitudes towards commercialization activities (Goldstein, Bergman, and Maier, 2012). University culture and an entrepreneurial climate are complementary to a university generating more licenses (Friedman and Silberman, 2003). Organizational culture of both the university and the firm can determine faculty inclinations to disclose, the types of inventions that the TTO pursues, the nature of university-industry interactions, etc. Therefore, some representation of university and industry cultures should be included in the alternative model of technology transfer.

Reward Systems

Related to university culture is the issue of university reward systems for faculty engaging in inventive activity, much less in technology transfer. Despite the guidelines of the Bayh-Dole Act requiring that faculty immediately disclose inventions to the TTO, in reality universities face the challenge of whether faculty scientists have sufficient incentives for disclosure and continued involvement in the technology transfer process after licenses are executed (Debackere and Veugelers, 2005). In many instances, technology is going "out the back door" as faculty members pursue alternative paths to commercializing their innovations.

Faculty attitudes are not always amenable to knowledge commercialization and technology transfer. Faculty disclosure and involvement is influenced in part by their perceptions of the ease of interacting with the TTO; difficulties interacting with the TTO can convince university scientists that the costs of IP protection outweigh the benefits (Owen-Smith and Powell, 2001; Link, Siegel, and Bozeman, 2007). University faculty who specialize in basic research may not disclose because they are unwilling to spend time conducting applied research and development that is often required for firms to be interested in licensing the invention (Thursby and Thursby, 2002). In addition, the faculty member must decide whether to disclose the invention as soon as it is a proof of concept or to wait until it is a lab-scale prototype (Jensen, Thursby, and Thursby, 2003).

Incentives for commercializing technology should appeal to faculty motivations. Baycan and Stough (2012b) find that traditional academic concerns, particularly the expectation of reputation and recognition, drive patenting and invention disclosure activities of scientists. Universities that provide greater rewards for faculty involvement in technology transfer will generate more licenses (Friedman and Silberman, 2003). Alternative financial incentive schemes are needed within universities, especially license contracts specifying an adequate share for the inventors in royalties or equity (Siegel, 2011; Debackere and Veugelers, 2005).

With regard to specific incentives, university scientists are entitled to salary supplements based on net proceeds from their contract research and consultancy activities, up to 30 percent of income generated in lump sum and royalty payments, and up to 40 percent of the IP shares in the case of spinoff creation (Debackere and Veugelers, 2005). Because lump sum payments provide no incentive for the scientist to engage in continued development, output-based payments, like royalties and equity, solve this moral hazard problem by linking the scientist's license income to additional effort (Jensen and Thursby, 2001). Lach and Schankerman (2003) find that high-powered pecuniary incentives strongly affect university research and licensing outcomes, and that universities with higher royalty shares generate higher levels of license income.

The traditional model ignores many aspect of a reward system and how it might affect the technology transfer process. However, adequate reward systems can significantly improve faculty involvement and universities' technology transfer success. As such, improved views should neither overlook nor underestimate the impact of reward systems.

Chapter 5 posits alternatives to the current traditional model that address these limitations and are more representative of technology transfer in practice.

5. Toward New Views of University Technology Transfer

This chapter builds on the traditional model by addressing its limitations and incorporating the concept of the entrepreneurial university and models of open innovation as applied to university technology transfer.

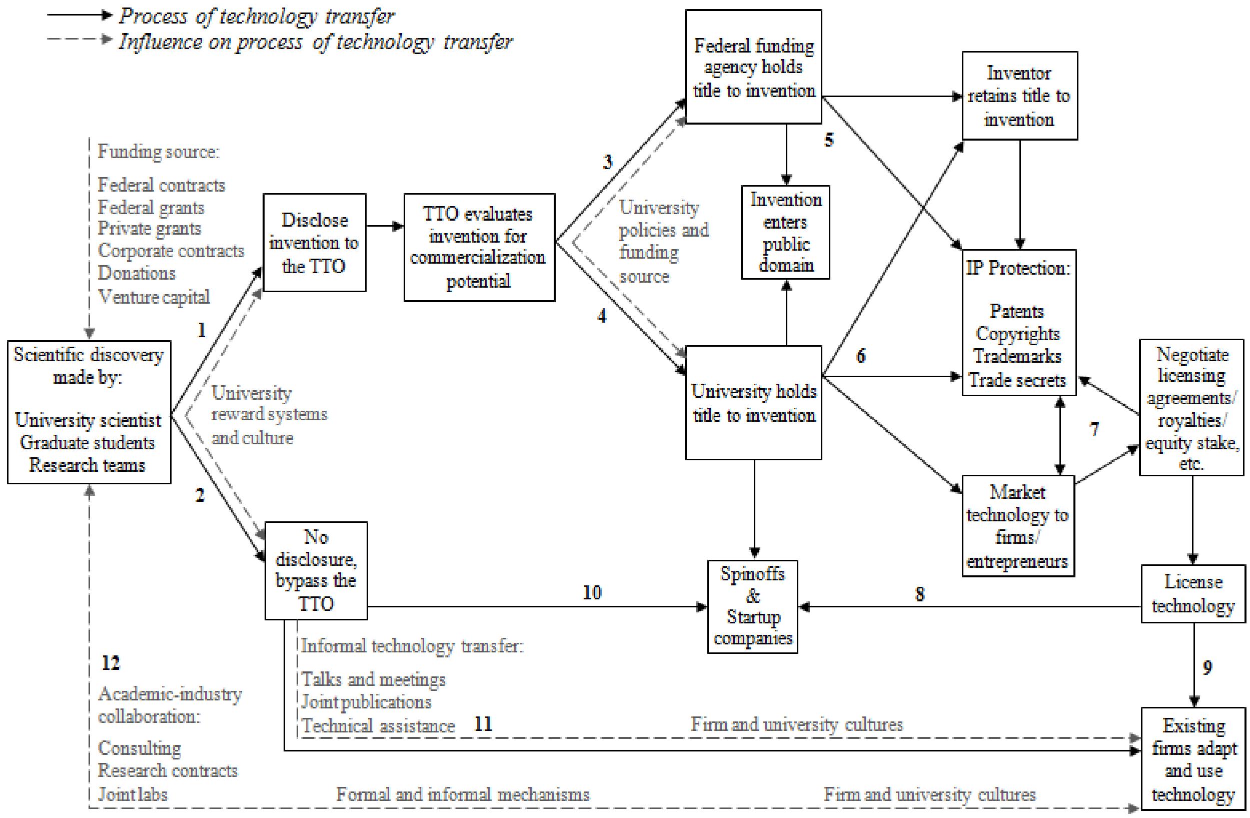
A dynamic, alternative view of technology transfer is offered herein. A degree of flexibility is introduced in the first proposed alternative view by rearranging some of the traditional components and creating additional paths for inventions to follow. The second proposed alternative view reaches beyond the context of the Bayh-Dole framework; it is a collaborative representation in which a web-based organization facilitates cooperation, innovation, and transparency between a conglomeration of university and industry participants. The presentation of these alternatives is more representative of technology transfer in practice, and is intended to facilitate a more efficient and effective technology transfer processes for universities. It is recognized that other views are possible.

To formulate an alternative view of technology transfer, it is useful to identify the various factors that contribute to the technology transfer process. Heinzl, Kor, Orange, and Kaufmann (2008) recognize factors that can influence university technology transfer performance: funding structures, research activities, the university's legal environment, and the institutional setting. Factors that enhance technology transfer include greater rewards for faculty involvement in technology transfer activities, proximity to regions with a concentration of high-tech firms, and the experience of the TTO (Friedman and Silberman, 2003).

Mechanisms of technology transfer include: joint laboratories between academia and business, spinoffs, licensing of IP, research contracts, mobility of researchers, joint publications, conferences, expositions and special media, informal contact within professional networks, and a flow of graduates to the industry (Heinzl, Kor, Orange, and Kaufmann, 2008). Bercovitz and Feldman (2006) also identify sponsored research, hiring of students, and serendipity as other mechanisms of technology transfer. These mechanisms create pathways of technology transfer that do not necessarily have to flow in one linear direction. These are all important components to consider in illustrating a dynamic view of technology transfer.

Figure 5 illustrates an alternative view of university technology transfer. The solid black arrows indicate processes of technology transfer, while the gray dashed arrows indicate factors that influence these processes.

Figure 5
Alternative Model of University Technology Transfer



This alternative view begins with a scientific discovery, as does the traditional model in Figure 1, but the alternative view distinguishes between different inventors—university scientists, graduate students, and research teams—that exist in practice. Also indicated in the beginning of this heuristic are the possible funding sources that facilitate discovery, including federal contracts, federal grants, private grants, corporate contracts, donations and venture capital funds.

Once a discovery is made, the technology transfer process follows one of two paths:

- The inventor can choose to disclose his/her invention to the university's TTO—Process 1 in Figure 5.

- The inventor can choose not to disclose his/her invention, bypassing the TTO—Process 2 in Figure 5.

The inventor's decision to disclose is influenced by the university's reward systems and culture, as noted by the gray dashed arrows. If the university has a reward system in place that provides incentives for faculty to engage in commercialization activities, the inventor might be more likely to disclose and participate in the formal mechanisms of technology transfer. If there are too many perceived barriers and disadvantages to involving the TTO and going through official channels, the inventor might circumvent disclosure and adopt informal mechanisms of technology transfer.

Once the inventor decides to disclose to the TTO, the office will evaluate the invention's commercialization potential, including the time it will take to bring the invention to market and its market potential (i.e. profitability). If the TTO decides to pursue the invention, the issue of which entity holds title to the invention becomes relevant. It is important to note that Process 3 in Figure 5 shows the case where the federal funding agency holds title to the invention rather than the university (Process 4). This possibility is included in order to depict a complete technology transfer process, as federal funding is still the most common source of funding. As acknowledged at the beginning of the model, there are certainly other sources of funding. For the private sources of funding (i.e., private grants, corporate contracts and donations), the university automatically holds title to the invention. Thus, the technology transfer process would simply move from the TTO to the decision on how to commercialize the invention (Process 6 in Figure 5).

When the discovery results from a federally-funded research project, under the SPRC (see Chapter 4 for more details), one of two paths might be followed:

- The university can decline to retain title; the federal funding agency can then request title to the invention—Process 3 in Figure 5.
- The university can retain title to the invention—Process 4 in Figure 5.

If the university declines to retain title to the invention, the responsibility goes to the federal agency that funded the discovery. As described in Section (f)(2) of the SPRC, the federal funding agency has three options (Process 5 in Figure 5):

- Request the title to the invention and let it enter the public domain, effectively ending the technology transfer process.
- Allow the inventor(s) to retain title to the invention, as long as the university approves. The inventor is then free to file their own application for IP protection.
- Request the title to the invention and file an application for IP protection, typically a patent.

Or, the university can choose to hold title to the invention and decide how to proceed with commercialization (Process 6 in Figure 5):

- In some cases, it is decided early on that a spinoff or startup is the best way to develop the invention.
- In other cases, the university markets the technology to firms or entrepreneurs that can develop the technology.
- The university may also begin the process of acquiring IP protection in the form of patents, copyrights, trademarks, trade secrets, etc.
- The university may, with the funding agency's approval, allow the inventor(s) to retain title to the invention.
- If the invention is not federally funded, it may be allowed to enter the public domain. This outcome typically occurs when the invention is unlikely to have significant commercial value, or there is no market interest or need for the invention.

Whether or not the university chooses to retain title to the invention depends largely on the technology transfer policies of the university. Some universities may take a more hands off approach to technology transfer and prefer to limit their involvement to conducting the research and leave the choice of what to do with the invention to the federal funding agency. Other universities may prefer to stand in for the federal agency and hold onto the title to the invention so they can undertake the responsibility of commercialization themselves. The extent to which a university traditionally engages in technology transfer activities may indicate which path to commercialization the discovery will likely follow. Process 3, where the federal funding agency holds title to the invention, is only an option if the inventor's research is in fact federally-funded.

The processes of marketing the invention, acquiring IP protection, and negotiating licensing agreements and pecuniary returns do not necessarily follow a linear path. These processes can overlap and occur simultaneously (Process 7 in Figure 5):

- The invention can be marketed before IP protection is acquired, that is, if the university wants to gauge market interest before investing significant time and resources to protecting the invention. Or, if the invention seems especially promising, the university might choose to apply for patents, copyrights, etc. before or even as they are marketing it to potential investors. The university could successfully market the invention, lock in an interested firm or entrepreneur, and begin licensing negotiations before the IP protection process is completed.
- If the federal funding agency holds title to the invention, its next step is to file patent applications.
- Similarly, if the inventor is permitted to retain title, he/she will likely seek IP protection before taking steps to commercialize and develop his/her invention.

Once the technology has been protected and successfully marketed, and a licensing agreement is concluded, the technology is officially licensed to a firm, organization, or entrepreneur. That is:

- If the technology has been licensed to an entrepreneur, such as the inventing faculty member or an outside party, a spinoff or startup company is established around the invention—Process 8 in Figure 5.
- If the technology has been licensed to an existing firm, the firm then adapts and uses the technology. Recall that the technology is typically embryonic and requires significant further development before reaching the market—Process 9 in Figure 5.

If the inventor chose to bypass the TTO (Process 2 in Figure 5), the technology transfer process is carried out through informal mechanisms. Informal technology transfer mechanisms include consulting, joint publications, presentations and conferences, and other communication processes between and among faculty members and industry contacts.

Informal technology transfer is more abstract than formal technology transfer in that it involves the exchange of ideas and knowledge rather than the property of a specific invention.

However, similar to the path of formal technology transfer, the ideas and knowledge that are passed along through informal mechanisms can also result in:

- A spinoff or a startup company being established that utilizes the knowledge passed on from the university scientist—Process 10 in Figure 5.
- The scientist's discovery, idea, or knowledge being adapted and used by an existing firm—Process 11 in Figure 5.
- Other forms of knowledge dissemination, including the disclosure of the invention into the public domain for others to use without cost.

When the university scientist chooses not to be involved in the formal technology path, he/she can take advantage of preexisting relationships with an industry contact and present his/her idea or discovery directly to them. Or, a person in industry may reach out to their university contact regarding a specific research interest or idea, thus initiating a two-way flow of communication. The firm has a connection to the resources and innovations within the university, and the university scientist has the opportunity to share his/her knowledge with industry contacts that can utilize it without the bureaucratic red tape of going through the TTO's official channels. Again, the decision to engage in informal technology transfer might depend on incentives to engage in formal technology transfer.

The firm's culture also impacts their decision to engage in informal technology transfer. Firms that are located near research universities, and firms that have long-term, well-established working relationships with universities, will be more likely to engage university faculty members in informal mechanisms of technology transfer.

Finally, the university scientist and the firm developing the invention often maintain a continued working relationship by means of academic-industry collaboration. The firm and university cultures must be favorable towards maintaining a partnership and engaging in technology transfer activities in order for collaborations to be successful.

Academic-industry collaboration can involve consulting, research contracts, the establishment of joint labs, and other partnerships between the university and the firm (Process 12 in Figure 5). These collaborations can involve both formal and informal mechanisms of technology transfer. Maintaining these relationships over time ensures that the university scientist continues to work with the firm to develop the embryonic invention and bring it to market thus providing a foundation for future technology transfer activities.

Although outside the scope of this paper, and thus not pictured in the alternative views, it should be mentioned that an entity related to technology transfer that is gaining popularity with universities is a proof of concept center (POC). POCs can be utilized to facilitate the transfer of university innovations into commercial applications (Gulbranson and Audretsch, 2008).[8]

POCs are organizations within or connected to the university that address the funding gap caused by investors who prefer to fund larger, later-stage enterprises by providing services to inventors which allow them to develop and prove their inventions as viable in the marketplace. Typical POC services include seed funding, business and advisory services, incubator space, and market research. The university's TTO typically coordinates with the POC by assisting with IP and licensing responsibilities, providing representatives for advisory services, and connecting inventors with outside funding sources.

POCs allow inventors to evaluate the commercial potential of their research; within POCs, early-stage products can be developed and prototypes can be tested. Proving a concept makes it easier for inventors to obtain funding from outside investors, like angel investors or venture capitalists, for further product development.

Following the notoriety of POCs such as the von Leibig Entrepreneurism Center at the University of California, San Diego and the Deshpande Center at MIT, POCs are becoming increasingly prevalent technology transfer entities or infrastructures within universities throughout the United States. Although they are not a direct component of the alternative view of technology transfer presented here, POCs can accelerate the commercialization of university inventions and increase the efficiency of the university technology transfer process.

The alternative view of technology transfer includes many of the same processes as the traditional model, but expands upon them and incorporates more elements of technology transfer in practice. Technology transfer is a complicated and dynamic process, and no single model can capture all of its nuances perfectly, hence the use of the term *views*. However, we believe that this is one alternative view that is an improvement over the traditional model.

Academic Entrepreneurship

[8] See Bradley, Hayter, and Link (forthcoming) for a more detailed discussion of proof of concept centers.

Universities have amplified their entrepreneurial activities over the past few decades, especially as innovation derived from university-industry collaborations are increasingly recognized for their contributions to firm innovation and, therefore, regional economic growth. Such growth occurs in part through the role of universities in regional technology development and revitalization (Bercovitz and Feldman, 2006). Shifting policy decisions, university cultures that value technology transfer, and greater emphasis on licensing royalties for research universities, have influenced the transformation towards more entrepreneurial universities (Rogers, Takegami, and Yin, 2001; Rothaermel, Agung, and Jiang, 2007; Baycan and Stough, 2012a). As such, it is prudent to incorporate the concept of academic entrepreneurship into the alternative model of technology transfer and into a discussion about the future of university technology transfer.

There is a burgeoning body of literature on the subject of academic entrepreneurship.[9] Academic entrepreneurship can refer to a wide range of activities with the goal of commercializing innovations developed by scientists at universities or federal labs (Siegel, 2011). This growing research interest coincides with a growing recognition among policymakers of the need to place more emphasis on knowledge creation and exploitation in the form of entrepreneurship by universities (Chiesa and Piccaluga, 2000). The future of alternative technology transfer may involve a transformation from an organization-centric model to an individual-centric model that enables academic entrepreneurs to apply their knowledge to solve local and regional economic challenges (Miller and Acs, 2012).

The so-called entrepreneurial university is both a knowledge-producer and a knowledge-disseminating institution that follows an interactive model of innovation, incorporating linear and reverse linear modes (Guerrero and Urbano, 2012; Etzkowitz, 2003a). The entrepreneurial university engages in innovative activities which facilitate economic development, job creation, and competitiveness in global markets.

Etzkowitz (2003a) suggests that academic entrepreneurship is both endogenous and exogenous. It is endogenous in the sense that entrepreneurship can be an internal development within the university stemming from its history and tradition, and it is exogenous in the sense that university innovation is facilitated in part by external influences. Van Looy, Ranga,

[9] See Rothaermel, Agung, and Jiang (2007); O'Shea, Allen, O'Gorman, and Roche (2004); Guerrero and Urbano (2012); Hayter (2009); Phan and Siegel (2006); and Siegel (2011) for comprehensive literature reviews regarding academic entrepreneurship.

Callaert, Debackere, and Zimmermann (2004) examine whether there is a tradeoff between entrepreneurial and scientific performance in academia. They find that engaging in both activities does not jeopardize one or the other; in fact, involvement in contract research seems to stimulate the scientific activities of divisions, resulting in larger publication outputs accumulating over time. Similarly, Baycan and Stough (2012b) find that commercialization and research excellence can go hand in hand, if the current focus on profit maximization, short-term benefits, and centralized structures is shifted toward value making, maximizing the volume of innovation, long-term benefits, and decentralized structures.

Hayter (2009) defines academic entrepreneurship as the establishment of new companies based on the research of university faculty. Indeed, university spinoffs are a primary output of academic entrepreneurship. Interviews conducted of academic entrepreneurs suggest that definitions of spinoff success include dissemination of knowledge, technology development, personal financial gain, and career motives. Hayter (2013) also identifies several factors that are critical to spinoff success. These include financial resources, previous spinoff experience, industry ties, faculty involvement, faculty or outside management, administrative, peer, or institutional support, TTOs, university IP policy, quality of life, multiple and outside licenses, joint ventures, university entrepreneurship services, the regional entrepreneurial environment, industry affiliation, and public policy. Hayter's work provides foundational insight into how universities can facilitate entrepreneurial activity and better ensure the success of university spinoffs.[10]

To engage in successful technology transfer in today's competitive and increasingly technological economies, it is imperative for universities to understand and embrace principles of entrepreneurship. University technology transfer is inherently an entrepreneurial activity, but simply participating in technology transfer activities does not make a university entrepreneurial. A university's culture must encourage and enable academicians and students to commercialize their inventions and intellectual property, and entrepreneurship should become an integral part of university missions (Kirby, 2006). Universities with an entrepreneurial culture tend to have a greater number of role models for faculty developing patentable inventions and starting new businesses (Goldstein, Bergman, and Maier, 2012). An entrepreneurial university integrates

[10] The term Valley of Death is generally attributed to Congressman Ehlers (2000) to refer to the lack of financial support that many (if not most) entrepreneurial endeavors face as they transcend from a technology to an innovation. That term is applicable in this instance to the creation and possible success of a spinoff.

economic development as an academic function alongside teaching and research and works with government and industry to facilitate the generation and exploitation of innovations (Etzkowitz, 1998; Leydesdorff and Meyer, 2003).

Academic entrepreneurship is commonly carried out through the creation of spinoff and startup companies. Both faculty and students can serve as academic entrepreneurs in the process. Graduate and post-doctoral students may be especially crucial to university spinoff development, particularly in the early stages (Boh, De-Haan, and Strom, 2012). By following guidelines such as aligning the objectives of the university, TTO, faculty, and graduate students; leveraging all potential university resources; and encouraging graduate students to see technology commercialization as a career option, universities can improve technology transfer and entrepreneurship (Boh, De-Haan, and Strom, 2012).

Spinoffs and startup companies can conclude the technology transfer process from several different paths within alternative view (in Figure 5, see Processes 6, 8, and 10). The alternative view presented here also demonstrates which processes are influenced by the university's level of entrepreneurship. The alternative view captures entrepreneurial mechanisms within the 'university reward systems' and 'university culture' elements (in Figure 5, see Processes 1, 2, 3, 4, 11, and 12). Including the variety of IP protections available demonstrates the options available to academic entrepreneurs for pursuing their inventions. Illustrating where spinoffs and startups and these entrepreneurial mechanisms come into play allows universities to recognize precisely when and where academic entrepreneurship has the biggest impact and highlights the importance of developing such activities. This alternative view provides a blueprint for universities incorporating entrepreneurial activities within the technology transfer process.

Open Innovation

The paradigm of Open Innovation, conceptualized by Chesbrough (2003a), ties into academic entrepreneurship and can be applied to alternative methods and views of technology transfer. The Open Innovation paradigm was originally directed towards innovation in large multinational corporations, such as Proctor and Gamble and IBM, but there is increasing interest in applying Open Innovation to other types of firms and institutions, including universities (Chesbrough, 2003b; Hayter, 2009).

In contrast to Open Innovation is the paradigm of Closed Innovation. Closed Innovation strategies were the norm for most of the 20^{th} century, wherein a company generates, develops, and commercializes its own ideas. Closed Innovation is hindered by its linearity and restrictiveness, which recalls the limitations of the traditional model of technology transfer discussed in the previous chapters. Towards the end of the 20^{th} century, as the number and mobility of knowledge workers rose and the availability of private venture capital increased, the effectiveness of Closed Innovation began to deteriorate. Many industries are now transitioning from Closed Innovation to Open Innovation, and this paradigm is increasingly relevant for the 21^{st} century university, as well.

The foundation of the Open Innovation concept is that innovators integrate their ideas, expertise, and skills with those of others outside the organization to deliver results to the marketplace using the most effective means possible (Chesbrough, 2003b). For universities, this means obtaining innovations from outside sources to augment their own R&D and entrepreneurial activities. For example, the university spinoff can license technology from other companies, their home university, and other research institutions and adopt a proactive, commercialization-centric approach to technology transfer (Hayter, 2009). Or, if a firm has a specific technical problem, it can extend its research channels and open up the problem to universities; ideas can originate outside the firm's laboratories and then be brought inside for commercialization (Chesbrough, 2003b). TTOs can facilitate this process by acting as knowledge and technology brokers, marketing patents and licenses to the interested firms.

Employing Open Innovation strategies can introduce multi-directional flows of knowledge and technology, allowing for more effective academic-industry collaborations. When knowledge and technology are able to flow freely to society and be transformed into useful applications, the innovations generated by universities will have the most efficient and significant impact on economic growth. Firms and universities that can embrace open, collaborative innovation strategies beyond the boundaries of their institutions will enjoy a competitive edge in today's global, decentralized technology transfer environment.

Collaborative View

Another identifiable, and somewhat more experimental, practice of technology transfer is what might be referred to as the collaborative view of knowledge and technology transfer.

Building off the concept of Open Innovation, a new method of technology transfer is gaining popularity that is characterized by low-cost, streamlined, transparent collaboration between participants. The collaborative model is better suited towards the transfer of knowledge than of physical inventions, although both can be accomplished within the view. The collaborative view is constructed from the examination of several collaborative organizations that have developed legal and technical infrastructures which allow participants to engage in knowledge- and idea-sharing that is a joint effort.

The original and most well-known of such organizations is Creative Commons. Creative Commons is a non-profit organization that released Creative Commons licenses, which allow creators to communicate which rights they reserve and which rights they waive for the benefit of recipients or other creators. Creative Commons licenses can be used in addition to traditional IP protections, with the added benefits of a standardized way for participants to keep their copyright while allowing certain specified uses of their creative, educational, or scientific works.[11]

Another organization employing similar practices that builds off the Creative Commons foundation is GreenXchange. GreenXchange is a project launched by Creative Commons in collaboration with industry giants Nike and Best Buy that helps holders of patents share intellectual property assets to accelerate sustainability innovations. GreenXchange provides a standardized patent license structure, whereby asset holders can control what levels and to whom their intellectual assets are available.[12] Participants are able to make both patented innovations and unpatented know-how available for use in research and commercialization while retaining the ability to choose their licensing approach. Both Creative Commons and GreenXchange focus on utilizing the Internet as a means of universal access to research and education, which drives innovation, economic growth and productivity.

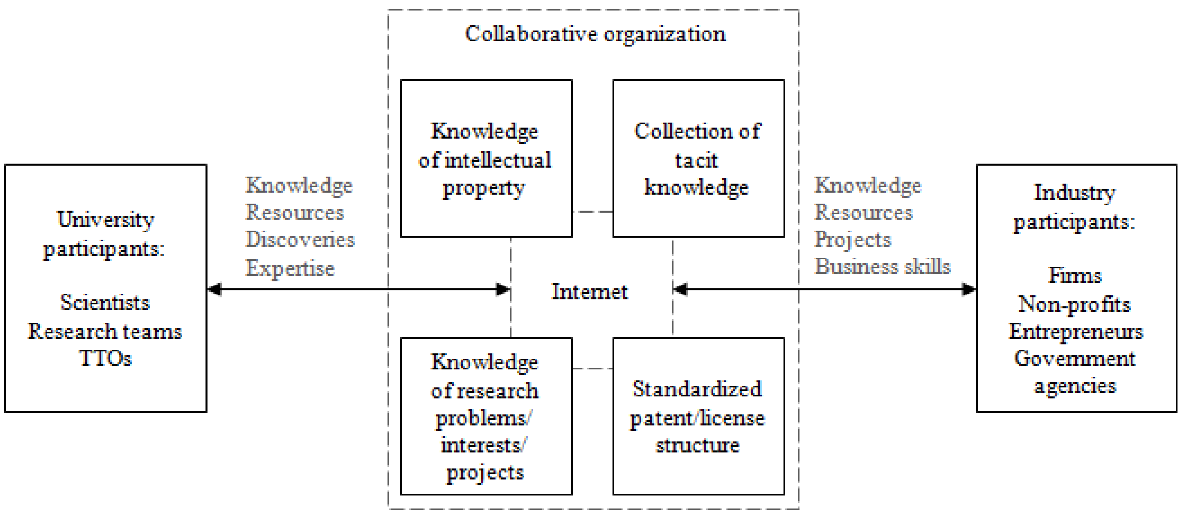
Similarly, the Sustainability Consortium is an organization launched by Walmart and jointly administered by Arizona State University and the University of Arkansas for the purpose of representing government, academic, and business interests develop a framework for sustainability product standards to enhance technology transfer.[13] The Sustainability Measurement & Reporting System (SMRS) framework is a common, global platform for companies to measure and report on product sustainability. The Sustainability Consortium is an

[11] See: http://creativecommons.org/about
[12] See: http://greenxchange.cc/info/about
[13] See: http://www.sustainabilityconsortium.org/smrs/

example of a collaborative knowledge transfer model in action; it is a conglomeration of institutions cooperating to develop methodologies, tools, and strategies that facilitate product development and innovation.

Figure 6 presents a collaborative view of knowledge and technology transfer.

Figure 6
Collaborative View of University Knowledge and Technology Transfer



In this view, academia and industry are able to connect directly through the Internet by means of a collaborative organization. The collaborative organization serves as a platform for matching innovators with the partners and resources they need to develop their product. They host, maintain, and promote their web-based organization as an alternative to traditional methods of knowledge and technology transfer. The collaborative organization facilitates the academic-industry connection by gathering data from all participating institutions, often cataloguing it into databases. Examples of collected data include:

- The intellectual property owned by the institutions, including copyrights, patents, etc.
- The tacit knowledge available from university or industry participants. This includes any notable un-patented know-how that is not protected and is free to utilize.
- Research problems, interests, or projects. For example, a firm could submit a request for a certain technology for which they seek help in developing. A university could share their research specialties and feature faculty members with area-specific

expertise. An entrepreneur could record their past and present commercialization projects.

- A standardized patent and/or license structure. This has been employed quite successfully by Creative Commons. Having a streamlined, standardized license structure allows the holder to control their assets while mitigating traditional research and negotiation methods and providing universal access to intellectual property.

Practices that emulate the collaborative view facilitate the technology transfer process by making knowledge transfer simple. The options provided by the collaborative organization allow innovations to be developed and commercialized as a joint effort, or released into the public domain to be used by any interested party. The benefits of organizations utilizing a collaborative view of technology transfer include reduced costs of technology transfer activities, a freer exchange of knowledge and ideas, and accelerating innovations to market.

Another strength of technology transfer practices within the collaborative view is the ease and flexibility with which innovations enter the public domain. The organizations employing such methods utilize the collaborative power of the Internet in ways uncommon within the traditional model in traditional practices of technology transfer. The collaborative model is in many ways the antithesis of the traditional linear model; it is fluid and continual, and allows knowledge and innovation to flow amongst participants with few limitations of structure or bureaucracy. In today's digital age, it seems advantageous to take advantage of the global connection the Internet provides and to formulate a method of technology transfer that is equally global and connective.

This collaborative view reaches outside the context of the Bayh-Dole framework. Its openness and flexibility allows participants to bypass the conventional channels and many of the boundaries of traditional technology transfer. The Bayh-Dole Act made innovation a commercial activity for universities. This alternative view makes innovation a collaborative activity amongst all participants and supplements traditional measures of commercial success (i.e., profitability) with the enrichment of the public domain.

Both of the alternative views of technology transfer and their associated methods are applicable across disciplines. While the traditional linear model best represented the path to market for homerun scientific technologies, the alternative views are adaptable for innovations in non-traditional fields. The first alternative model, presented in Figure 5, captures enough processes of the technology transfer process for it to be sufficiently general to apply to most technologies. It also encompasses the majority of potential technology transfer strategies. The collaborative model is especially relevant for creative works and knowledge-based inventions.

6. Conclusions

This paper argues that a linear model of technology transfer is no longer sufficient, or perhaps even no longer relevant, to account for the nuances and complexities of university technology transfer practices. Shortcomings of the traditional linear model include inaccuracies—such as its strict linearity and oversimplification of the process, composition, a one-size-fits-all approach, and an overemphasis on patents—and inadequacies—such as failing to account for informal mechanisms of technology transfer, failing to acknowledge the impact of organizational culture, and failing to represent university reward systems within the model. As such, a linear view may in fact drive practices that mediate the dissemination and commercialization of new technologies. Accordingly, two alternative views are presented that better capture the progression of the university towards an entrepreneurial institution and engine of economic growth.

The 21st century university is an entrepreneurial university with a mission of economic development in addition to research and teaching, and an interdisciplinary organizational structure that facilitates knowledge-based innovation (Etzkowitz, Webster, Gebhardt, and Terra, 2000; Rothaermel, Agung, and Jiang, 2007). A university in which research is routinely scrutinized for both commercial and scientific potential is becoming the prevailing academic institution (Etzkowitz, 2003). Universities need to be entrepreneurial institutions in order to fulfill their purpose of fostering creativity and responsiveness to scientific, technological, and economic changes in society (Grigg, 1994). Such universities have the internal capabilities to translate research results into intellectual property and economic activity.

It seems that technology transfer will become more important to economic development over time. Through technology transfer, universities contribute to the stock of technical knowledge and technologies that firms can draw on for innovation and hence economic growth (Bercovtiz and Feldman, 2006). Also, the growing entrepreneurial activity of American universities is connected to another trend—an intensifying of the links between research and innovation (Hicks, Olivastro, and Hamilton, 2001). Thus, it is important that universities continue to develop their technology transfer practices along with their research activities and that federal policy supports universities becoming more entrepreneurial.

In order to facilitate future technology transfer success and continued economic growth and competitiveness, several changes must occur. First, universities will have to overcome barriers to technology transfer. These include informational and cultural barriers such as insufficient rewards for university researchers, university-industry culture clashes, bureaucratic inflexibility, unskilled and understaffed TTOs, lack of entrepreneurial talent throughout the university, the perception of declining federal R&D support, and the concern that university-industry cooperation will interfere with academic freedom, and—arguably—the existence of the traditional linear view of technology transfer itself (Siegel, Waldman and Link, 2003; Lee, 1996; Kirby, 2006; Behrens and Gray, 2001).

Conquering these barriers will require universities to create more incentives for faculty members to engage in entrepreneurial activities, such as rewarding technology transfer in promotion and tenure decisions (Siegel, Waldman and Link, 2003). Faculty should be educated about commercial opportunities. This would include not only working with their TTO—or other boundary spanning organizations—but also learning project management and other business practices to ensure successful academic-industry cooperation (Laukkanen, 2003). Personal relationships between scientists and industry contacts should also be fostered as they might prove even more important than contractual relationships (Siegel, Waldman, Atwater, and Link, 2004).

It is also important that the organizational structure of universities is constructed to facilitate seamless technology transfer activities. An appropriate organizational structure may include a specialized and decentralized TTO with sufficient autonomy to develop relationships with industry, within the context of a supportive institutional and policy environment (Debackere and Veugelers, 2005). Universities need better staffing practices for TTOs; TTO staff need marketing, technical and negotiation skills (Siegel, Waldman, Atwater, and Link, 2004). TTO staff must understand the culture and function of the academic enterprise and of the industry sector to put together licensing deals (Powers and McDougall, 2005). A properly organized and staffed TTO can greatly increase the productivity of a university's technology transfer activities. Or universities could conceivably pursue organizational options that focus less on intellectual property protection and more on other, more effective means for disseminating and commercializing new technologies.

Certainly the alternative views presented in this paper are yet imperfect representations of reality, and will not be representative of, or applicable to, every invention across disciplines.

Still, these alternative views advance the body of thought about university technology transfer, and are thus one starting point not only for more efficient and effective practiced technology transfer, but also for how academic scholars perceive that process. Academic entrepreneurship and open innovation practices will evolve and become part of the technology transfer process in the future. It is thus important for universities to adapt technology transfer strategies that embrace these developments sooner rather than later, just as technology transfer scholars should expand and reinvigorate their research focus on these emerging areas.

References

Association of University Technology Managers, http://www.autm.net/Bayh_Dole_Act.htm.

Association of University Technology Managers (2011) U.S. Licensing Activity Survey Highlights: Fiscal Year 2010.

Barnett, G. Research Enterprise Blog, '37 CFR 401.9.' Last modified November 4, 2010. Accessed February 29, 2012. http://rtei.org/blog/2010/11/04/37-cfr-401-9/.

Barnett, G. Research Enterprise Blog, 'Mapping Bayh-Dole Flow of Control.' Last modified June 24, 2011. Accessed February 20, 2012. http://rtei.org/blog/2011/06/24/mapping-bayh-dole-flow-of-control/.

Baycan, T. and R. R. Stough (2012a), 'Introduction: commercialization of knowledge in a regional context: new perspectives,' *Annals of Regional Science*, Special Issue Editorial.

Baycan, T. and R. R. Stough (2012b), 'Bridging knowledge to commercialization: The good, the bad, and the challenging,' *Annals of Regional Science*, Special Issue Paper.

Bayh-Dole Act, 1980, Patent and Trademark Act Amendments, P.L. 96-517, Standard Patent Rights Clauses 37 C.F.R. 401.14.

Behrens T. R. and D. O. Gray (2001), 'Unintended consequences of co-operative research: impact of industry sponsorship on climate for academic freedom and other graduate student outcome,' *Research Policy*, 30(2), 179-199.

Bell, E.R.J. (1993), 'Some current issues in technology transfer and academic-industrial relations: a review,' *Technology Analysis and Strategic Management*, 5(3), 307-321.

Bercovitz, J., M. Feldman, I. Feller and R. Burton (2001), 'Organizational structure as a determinant of academic patent and licensing behavior: an exploratory study of Duke, Johns Hopkins, and Pennsylvania State Universities,' *Journal of Technology Transfer*, 26(1-2), 21-35.

Bercovitz, J. and M. Feldman (2006), 'Entrepreneurial universities and technology transfer: a conceptual framework for understanding knowledge-based economic development,' *Journal of Technology Transfer*, 31(1), 175-188.

Boh, W. F., U. De-Haan, and R. Strom (2012), 'University technology transfer through entrepreneurship: Faculty and students in spinoffs,' Ewing Marion Kauffman Foundation.

Bozeman, B. (2000), 'Technology transfer and public policy: a review of research and theory,' *Research Policy*, 29(4-5), 627-655.

Bradley, S.R., C.S. Hayter, and A.N. Link (forthcoming). 'Proof of concept centers in the United States: an exploratory look,' *Journal of Technology Transfer*.

Bray, M.J. and J.N. Lee (2000), 'University revenues from technology transfer: licensing fees versus equity positions,' *Journal of Business Venturing*, 15(5-6), 385-392.

Branscomb, L.M. and P.E. Auerswald (1992*). Between invention and innovation An analysis of funding for early-stage technology development*, Washington, DC: U.S. Department of Commerce.

Carayannis, E.G., E.M. Rogers, K. Kurihara and M.M. Allbritton (1998), 'High-technology spin-offs from government R&D laboratories and research universities,' *Technovation*, 18(1), 1-11.

Carlsson, B. and A. Fridh (2002), 'Technology transfer in United States universities: A survey and statistical analysis,' *Journal of Evolutionary Economics*, 12, 199-232.

Cassar, G. (2007), 'Money, money, money? A longitudinal investigation of entrepreneur career reasons, growth preferences and achieved growth,' *Entrepreneurship & Regional Development*, 19(1), 89-107.

Chesbrough, H. (2003a), *Open innovation: the new imperative for creating and profiting from technology*, Boston, Harvard Business School Press.

Chesbrough, H. (2003b), 'The era of open innovation,' *MIT Sloan Management Review*, 44(3), 35-41.

Chiesa, V. and A. Piccaluga (2000), 'Exploitation and diffusion of public research: the case of academic spin-off companies in Italy,' *R&D Management*, 30(4), 329-340.

Clarysse, B. and N. Moray (2004), 'A process study of entrepreneurial team formation: the case of a research-based spin-off,' *Journal of Business Venturing*, 19(1), 55-79.

Clarysse, B., V. Tartari, and A. Salter (2011), 'The impact of entrepreneurial capacity, experience and organizational support on academic entrepreneurship,' *Research Policy*, 40(8), 1084-1093.

Clarysse, B., M. Wright, A. Lockett, P. Mustar and M. Knockaert (2007), 'Academic spin-offs, formal technology transfer and capital raising,' *Industrial and Corporate Change*, 16(4), 609-640.

Clarysse, B., M. Wright, A. Lockett, E. Van de Velde and A. Vohora (2005), 'Spinning out new ventures: a typology of incubation strategies from European research institutions,' *Journal of Business Venturing*, 20(2), 183-216.

Cohen, W., R. Florida, L. Randazzese, and J. Walsh (1998),'Industry and the academy: uneasy partners in the cause of technological advance,' in R. Noll (ed.), *Challenges to the Research University*, Brookings Institution, Washington, D.C.

Colyvas, J., M. Crow, A. Gelijns, R. Mazzoleni, R.R. Nelson, N. Rosenberg, and B.N. Sampat (2002), 'How do university inventions get into practice?' *Management Science*, 48(1), 61-72.

Coupe, T. (2003), 'Science is golden: academic R&D and university patents,' *Journal of Technology Transfer*, 28(1), 31-46.

Creative Commons, 'About,' http://creativecommons.org/about.

Debackere, K. and R. Veugelers (2005), 'The role of academic technology transfer organizations in improving industry science links,' *Research Policy*, 34(3), 321-342.

Di Gregorio, D. and S. Shane (2003), 'Why do some universities generate more start-ups than others?,' *Research Policy*, 32(2), 209-227.

Druilhe, C. and E. Garnsey (2004), 'Do academic spin-outs differ and does it matter?,' *Journal of Technology Transfer*, 29(3-4), 269-285.

Dueker, K.S. (1997), 'Biobusiness on campus: commercialization of university-developed biomedical technologies,' *Food and Drug Law Journal*, 52, 453-509.

Ehlers, V. (2000). Unpublished lecture to the conference on basic research in service of national objectives. November 28 as referenced in Branscomb and Auerswald (2002).

Etzkowitz, H. (1983), 'Entrepreneurial scientists and entrepreneurial universities in American academic science,' *Minerva*, 21(2-3), 198-233.

Etzkowitz, H. (2003a), 'Research groups as 'quasi-firms': the invention of the entrepreneurial university,' *Research Policy*, 32(1), 109-121.

Etzkowitz, H. (2003b), 'Innovation in innovation: the triple helix of university-government-industry relations,' *Social Science Information*, 42(3), 293-337.

Etzkowitz, H., A. Webster, C. Gebhardt, and B. Terra (2000), 'The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm,' *Research Policy*, 29(2), 313-330.

Feldman, M. and P. Desrochers (2003), 'Research universities and local economic development: lessons from the history of Johns Hopkins University,' *Industry and Innovation*, 10(1), 5-24.

Fontes, M. (2005), 'The process of transformation of scientific and technological knowledge into economic value conducted by biotechnology spinoffs,' *Technovation*, 25(4), 339-347.

Friedman, J. and J. Silberman (2003), ‘University technology transfer: do incentives, management, and location matter?’ *Journal of Technology Transfer*, 28(1), 17-30.

Genet, C., K. Errabi and C. Gauthier (2012), ‘Which model of technology transfer for nanotechnology? A comparison with biotech and microelectronics,’ *Technovation*, 32(3-4), 205-215.

Geuna, A., and A. Muscio (2009), ‘The governance of university knowledge transfer: a critical review of the literature,’ *Minerva*, 47(1), 93-114.

Geuna, A. and L. Nesta (2006), ‘University patenting and its effects on academic research: the emerging European evidence,’ *Research Policy*, 35(6), 790-807.

Goble, L. (2012), ‘Why and how to pursue creative works,’ Presented at the AUTM Annual Meeting, March 15, 2012.

Göktepe-Hulten D. and P. Mahagaonkar (2010), ‘Inventing and patenting activities of scientists: in the expectation of money or reputation?’ *Journal of Technology Transfer*, 35, 401-423.

Goldhor, R. and R.Lund (1983), ‘University-to-industry advanced technology transfer,’ *Research Policy*, 12(3), 121-152.

Goldstein, H., E. M. Bergman, and G. Maier (2012), ‘University mission creep? Comparing EU and US faculty views of university involvement in regional economic development and commercialization,’ *Annals of Regional Science,* Special Issue Paper.

Golub, E. (2003) *Generating Spin-off from University Based Research: The Potential of Technology Transfer.* Ph.D. Dissertation, Columbia University.

Grandi, A. and R. Grimaldi (2005), ‘Academics’ organizational characteristics and the generation of successful business ideas,’ *Journal of Business Venturing*, 20(6), 821-845.

GreenXchange, ‘About the GreenXchange,’ http://greenxchange.cc/info/about.

Grigg, T. (1994), ‘Adopting an entrepreneurial approach in universities,’ *Journal of Engineering and Technology Management*, 11(3-4), 273-298.

Grimpe, C. and H. Fier (2010), ‘Informal university technology transfer: a comparison between the United States and Germany,’ *Journal of Technology Transfer*, 35(6), 637-650.

Guerrero, M. and D. Urbano (2012), ‘The development of an entrepreneurial university,’ *Journal of Technology Transfer*, 37(1), 43-74.

Gulbranson, C.A. and D.B. Audretsch (2008), ‘Proof of concept centers: accelerating the commercialization of university innovation,’ *Journal of Technology Transfer*, 33(3), 249-258.

Harmon, B., A. Ardishvili, R. Cardozo, T. Elder, J. Leuthold, J. Parshall, M.Raghian, and S. Donald (1997), ‘Mapping the university technology transfer process,’ *Journal of Business Venturing*, 12(6), 423-434.

Hayter, C. (2009), ‘The open innovation imperative: perspectives on success from faculty entrepreneurs,’ Ph.D. Dissertation, George Washington University.

Hayter, C. (2011), ‘In search of the profit-maximizing actor: motivations and definitions of success from nascent academic entrepreneurs,’ *Journal of Technology Transfer,* 36(3), 340-352.

Hayter, C. (2013), ‘Harnessing university entrepreneurship for economic growth: Factors of success among university spinoffs,’ *Economic Development Quarterly*, *forthcoming*.

Heinzl, J., A. Kor, G. Orange and H. Kaufmann (2008), ‘Technology transfer model for Austrian higher education institutions,’ presented at the European and Mediterranean Conference on Information Systems, May 25-26, 2008.

Henderson, R., A.B. Jaffe and M. Trajtenberg, ‘Universities as a source of commercial technology: a detailed analysis of university patenting, 1965-1988,’ *Review of Economics and Statistics*, 80(1), 119-127.

Hicks, D., T. Breitzman, D. Olivastro, and K. Hamilton (2001), ‘The changing composition of innovative activity in the U.S. – a portrait based on patent analysis,’ *Research Policy*, 30(4), 681-703.

Jensen, R.A. and M.C. Thursby (2001), ‘Proofs and prototypes for sale: the licensing of university inventions,’ *American Economic Review*, 91(1), 240-259.

Jensen, R. A., J. G. Thursby and M. C. Thursby (2003), ‘Disclosure and licensing of university inventions: ‘the best we can do with the S**T we get to work with?,’ *International Journal of Industrial Organization*, 21(9), 1271-1300.

Kenney, M. and W. R. Goe (2004), ‘The role of social embeddedness in professorial entrepreneurship: a comparison of electrical engineering and computer science at UC Berkeley and Stanford,’ *Research Policy*, 33(5), 691-707.

Kenney, M. and D. Patton (2009), ‘Reconsidering the Bayh-Dole Act and the current university invention ownership model,’ *Research Policy*, 38, 1407-1422.

Kerr, C. (2001) *The uses of the university*. Harvard University Press, Cambridge, MA.

Kim, Y. (2011), ‘The ivory tower approach to entrepreneurial linkage: productivity changes in university technology transfer,’ *Journal of Technology Transfer*, (Preprint), 1-18.

Kirby, D. A. (2006), ‘Creating entrepreneurial universities in the UK: applying entrepreneurship theory to practice,’ *Journal of Technology Transfer*, 31(5), 599-603.

Kumar, M. N. (2010), ‘Ethical conflicts in commercialization of university research in the post-Bayh Dole era,’ *Ethics and Behavior*, 20(5), 324-351.

Lach, S. and M. Schankerman (2008), ‘Incentives and invention in universities,’ *The RAND Journal of Economics*, 39(2), 403-433.

Lee, Y.S. (1996), ‘‘Technology transfer’ and the research university: a search for the boundaries of university-industry collaboration,’ *Research Policy*, 25(6), 843-863.

Lee, Y.S. (2000), ‘The sustainability of university-industry research collaboration: an empirical assessment,’ *Journal of Technology Transfer*, 25(2), 111.

Lee, J. and H.N. Win (2004), ‘Technology transfer between university research centers and industry in Singapore,’ *Technovation*, 24(5), 433-442.

Leitch, C. M. and R. T. Harrison (2005), ‘Maximising the potential of university spin-outs: the development of second-order commercialisation activities,’ *R & D Management*, 35(3), 257-272.

Lerner, J. (2005), ‘The university and the start-up: lessons from the past two decades,’ *Journal of Technology Transfer*, 30(1-2), 49-56.

Levin, R.C., A. Klevorick, R.R. Nelson, and S. Winter (1987), ‘Appropriating the returns from industrial research and development,’ *Brookings Papers on Economic Activity*, 783-820.

Leydesdorff, L. and M. Meyer (2003), ‘The triple helix of university-industry-government relations,’ *Scientometrics*, 58(2), 191-203.

Leydesdorff, L. and M. Meyer (2012), ‘Technology transfer and the end of the Bayh-Dole effect: Patents as an analytical lens on university-industry-government relations,’ forthcoming in *Scientometrics*.

Link, A.N., and J.T. Scott (2005), ‘Opening the ivory tower’s door: an analysis of the determinants of the formation of U.S. university spin-off companies,’ *Research Policy*, 34(7), 1106-1112.

Link, A.N., D.S. Siegel, and B. Bozeman (2007), ‘An empirical analysis of the propensity of academics to engage in informal university technology transfer,’ *Industrial and Corporate Change*, 16(4), 641-655.

Litan, R., L. Mitchell, and E. Reedy (2007), ‘The university as innovator: bumps in the road,’ *Issues in Science and Technology*, 23(4), 57-66.

Lockett, A. and M. Wright (2005), ‘Resources, capabilities, risk capital and the creation of university spin-out companies,’ *Research Policy*, 34(7), 1043-1057.

Lowe, R. (2002), ‘Invention, innovation and entrepreneurship: the commercialization of university research by inventor-founded firms,’ PhD dissertation, University of California at Berkeley.

Macho-Stadler, I., X. Martinez-Giralt, and J.D. Perez-Castrillo (1996), ‘The role of information in licensing contract design,’ *Research Policy*, 25(1), 43-57.

Markman, G.D., P.T. Gianiodis, P.H. Phan and D.B. Balkin (2004), ‘Entrepreneurship from the ivory tower: do incentive systems matter?,’ *Journal of Technology Transfer*, 29(3-4), 353-364.

Markman, G.D., P.T. Gianiodis, P.H. Phan and D.B. Balkin (2005), ‘Innovation speed: transferring university technology to market,’ *Research Policy*, 34(7), 1058-1075.

Markman, G.D., P.H. Phan, D.B. Balkin and P.T. Gianiodis (2005), ‘Entrepreneurship and university-based technology transfer,’ *Journal of Business Venturing*, 20(2), 241-263.

Mitchel, W. (1991), ‘Using academic technology: transfer methods and licensing incidence in the commercialization of American diagnostic imaging equipment research, 1954-1988,’ *Research Policy*, 20, 203-216.

Mowery, D.C. (2009), ‘The Bayh-Dole Act and high-technology entrepreneurship in the United States during the 1980s and 1990s,’ in Z.J. Acs, D.B. Audretsch and R.J. Strom (eds.), *Entrepreneurship, Growth, and Public Policy*, New York: Cambridge University Press, 2009.

Mowery, D.C., R.R. Nelson, B.N. Sampat and A.A. Ziedonis (2001), ‘The growth of patenting and licensing by the U.S. universities: an assessment of the effects of the Bayh-Dole Act of 1980,’ *Research Policy*, 30(1), 99-119.

Nerkar, A. and S. Shane (2003), ‘When do start-ups that exploit patented academic knowledge survive?,’ *International Journal of Industrial Organization*, 21(9), 1391-1410.

O’Shea, R.P., Allen, T.J., Chevalier, A., and F. Roche (2005), ‘Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities,’ *Research Policy*, 34(7), 994-1009.

O’Shea, R. Allen, T.J., O’Gorman, C., and F. Roche (2004), ‘Universities and technology transfer: a review of academic entrepreneurship literature,’ *Irish Journal of Management*, 25(2), 11-29.

Owen-Smith, J. and W.W. Powell (2001), ‘To patent or not: faculty decisions and institutional success at technology transfer,’ *Journal of Technology Transfer*, 26(1-2), 99-114.

Phan, P.H. and D.S. Siegel (2006), ‘The effectiveness of university technology transfer,’ *Foundations and Trends in Entrepreneurship*, 2(2), 74-144.

Powers, J.B. and P.P. McDougall (2005), ‘University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship,’ *Journal of Business Venturing*, 20(3), 291-311.

Rasmussen, E. and R. Sorheim (2012), ‘How governments seek to bridge the financing gap for university spin-offs: proof-of-concept, pre-seed, and seed funding,’ *Technology Analysis & Strategic Management*, 24(7), 663-678.

Reynolds, P.D., S.M. Camp, W.D. Bygrave, E. Autio, and M. Hay (2001), ‘*Global Entrepreneurship Monitor 2001 Executive Report*.’

Roberts, E.B. and D.H. Peters (1981), ‘Commercial innovation from university faculty,’ *Research Policy*, 10(2), 108-126.

Rogers, E.M., S. Takegami, and J. Yin (2001), ‘Lessons learned about technology transfer,’ *Technovation*, 21(4), 253-261.

Rosenberg, N. and R.R. Nelson (1994), ‘American universities and technical advance in industry.’ *Research Policy*, 23(3), 323-348.

Rothaermel, F., S. Agung, and L. Jiang (2007), ‘University entrepreneurship: a taxonomy of the literature,’ *Industrial and Corporate Change*, 16(4), 691-791.

Saragossi, S. and B. van Pottelsberghe de la Potterie (2003), ‘What patent data reveal about universities: the case of Belgium,’ *Journal of Technology Transfer*, 28(1), 47-51.

Shane, S. (2002), ‘Executive forum: university technology transfer to entrepreneurial companies,’ *Journal of Business Venturing*, 17(6), 537-552.

Shane, S. (2004a), ‘*Academic Entrepreneurship: University Spinoffs and Wealth Creation*,’ Cheltenham, UK, Edward Elgar.

Shane, S. (2004b), ‘Encouraging university entrepreneurship? The effect of the Bayh-Dole Act on university patenting in the United States,’ *Journal of Business Venturing*, 19(1), 127-151.

Siegel, D.S. (2011), ‘Academic entrepreneurship: lessons learned for university administrators and policymakers,’ Presented at the Strategic Management of Places Conference, December 13, 2011.

Siegel, D.S., D.A. Waldman, L. Atwater and A.N. Link (2004), ‘Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies,’ *Journal of Engineering and Technology Management*,’ 21(1-2), 115-142.

Siegel, D.S., D.A. Waldman and A.N. Link (2003), ‘Assessing the impact of organizational practices on the productivity of university technology transfer offices: an exploratory study,’ *Research Policy,* 32(1), 27-48.

Siegel, D.S. and P.H. Phan (2005), ‘Analyzing the effectiveness of university technology transfer: implications for entrepreneurship education,’ in G. Liebcap (ed.), *Advances in the study of entrepreneurship, innovation, and economic growth*. Elsevier Science/JAI Press: Amsterdam, 1-38.

Sine, W.D., S. Shane, and D. Di Gregorio (2003), ‘The halo effect and technology licensing:the influence of institutional prestige on the licensing of university inventions,’ *Management Science*, 49(4), 478-496.

Slaughter S. and G. Rhoades (2004), *Academic capitalism and the new economy: markets, states and higher education,* Johns Hopkins University Press, Baltimore.

Steffensen, M., E.M. Rogers, and K. Speakman (2000), ‘Spin-offs from research centers ata research university,’ *Journal of Business Venturing*, 15(1), 93-111.

Sustainability Consortium, ‘Sustainability measurement & reporting system (SMRS),’ http://www.sustainabilityconsortium.org/smrs/.

Tata, G. (2012), ‘Marketing and selling creative works,’ Presented at the AUTM Annual Meeting, March 15, 2012.

Thursby, J.G., R.A. Jensen and M.C. Thursby (2001), ‘Objectives, characteristics and outcomes of university licensing: a survey of major U.S. universities,’ *Journal of Technology Transfer,* 26(1-2), 59-70.

Thursby, J.C. and M.C. Thursby (2002), ‘Who is selling the ivory tower? Sources of growth in university licensing,’ *Management Science*, 48(1), 90-104.

Thursby, J. G. and S. Kemp (2002), ‘Growth and productive efficiency of university intellectual property licensing,’ *Research Policy*, 31(1), 109-124.

U.S. Patent and Trademark Office (2011) Current Fee Schedule http://www.uspto.gov/web/offices/ac/qs/ope/fee092611.htm

U.S. Patent and Trademark Office (2011) ‘General Information Concerning Patents.’ http://www.uspto.gov/patents/resources/general_info_concerning_patents.jsp

van Dierdonck R. and K. Debackere (1988), ‘Academic entrepreneurship at Belgian universities,’ *R&D Management*, 18(4), 341-353.

Van Looy, B., Ranga, M., Callaert, J., Debackere, K., and E. Zimmermann (2004), 'Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew effect?' *Research Policy*, 33(3), 425-441.

Vohora, A., M. Wright and A. Lockett (2004), 'Critical junctures in the development of university high-tech spinout companies,' *Research Policy*, 33(1), 147-175.

Wright,M., B. Clarysse, P. Mustar, and A. Lockett (2007), *Academic entrepreneurship in Europe*, London, Edward Elgar.

Wright, M., Mosey, S., and H. Noke (2011), 'Academic entrepreneurship and economic competitiveness: rethinking the role of the entrepreneur," Keynote Paper: International Conference on Academic Entrepreneurship: Basque Institute of Competitiveness (San Sebastian, Spain), September 8-9, 2011.