EVALUATING THE INFLUENCE OF UNIVERSITY ORGANIZATIONAL CHARACTERISTICS AND ATTRIBUTES ON TECHNOLOGY COMMERCIALIZATION

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ABSTRACT

LISA A. GOBLE: Evaluating the Influence of University Organizational Characteristics and Attributes on Technology Commercialization
(Under the direction of Maryann Feldman)

This dissertation project seeks to make a contribution to the growing body of literature on academic technology commercialization and the entrepreneurial efforts of faculty and students at US research universities. The academic environment across the United States has seen an increased emphasis on moving the results of academic research into the commercial sector. In addition to their core missions of education and basic research, universities are expected to have a larger role in stimulating regional and national economies. This dissertation project contributes to this growing body of literature on university technology commercialization efforts by summarizing findings on characteristics and factors known to have an influence technology transfer outcomes, evaluating a technology licensing consortium between three large research institutions, and empirically evaluating specific university and technology licensing office characteristics for their influence on the technology transfer process and its outcomes.

Three related research studies contribute to this project. The motivating framework, background and context for the three research projects in this dissertation are presented in an introductory chapter. The literature review in Chapter 2 summarizes findings from a selection of studies evaluating characteristics and attributes of US universities, their technology licensing offices (TLOs), and regions that have an influence upon a university's involvement in technology commercialization efforts. Findings are summarized for how various characteristics influence the technology transfer process, invention disclosure from faculty, and subsequent licensing and startup formation form US research universities. Chapter 3 presents a case study of an early technology

licensing consortium between three North Carolina universities: Duke University, The University of North Carolina at Chapel Hill, and North Carolina State University during 1988-1995. This consortium facilitated a growing entrepreneurial culture, increased patenting and technology licensing activities at each campus, and enabled the successful licensing of several academic inventions. In Chapter 4, an empirical analysis utilizes survey data from 76 universities to review potential correlations between university organizational and TLO characteristics and the metrics commonly reported by US research universities engaged in technology transfer. This research fills a gap in the literature by evaluating the potential influence TLO organizational reporting structure and characteristics of the TLO director may have on the technology commercialization efforts and outcomes of US research institutions. Chapter 5 integrates the general findings from the three projects, and outlines the significance of those findings for how characteristics of the university and TLO influence the technology transfer process and its outcomes. Implications and recommendations for university administrators and for policy development within the US university environment and their economic regions are discussed in this final chapter.

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LIST OF ABBREVIATIONS

AUTM	Association of University Technology Managers
BEA	Bureau of Economic Assistance
BS/BA	Bachelor of Science, Bachelor of Arts
DEA	Data Envelope Analysis
GDP	Gross Domestic Product
GEE	Generalized Estimating Equations
H.L.	House Legislation
IP	Intellectual Property
IPO	Initial Public Offering
JD	Juris Doctorate
LES	Licensing Executive Society
MBA	Master of Business Administration
MCNC	Microelectronics Center of North Carolina
MSA	Metropolitan Statistical Area
NC	North Carolina
NCBC	North Carolina Biotechnology Center
NCSU	North Carolina State University
NIH	National Institute of Health
NSF	National Science Foundation
NRC	National Research Council
OLS	Ordinary Least Squares
P.L.	Public Law
R&D	Research & Development
ROI	Return on Investment

RTI	Research Triangle Institute
RTP	Research Triangle Park
SBIR	Small Business Innovation Research
STTR	Small Business Technology Transfer
SBTDC	Small Business Technology Development Center
SFE	Stochastic Frontier Estimation
STATT	Statistics Access for Tech Transfer
TFP	Total Factor Productivity
TLO	Technology Licensing Office
TT	Technology Transfer
TULCO	Triangle University Licensing Consortium
TUCASI	Triangle Universities Center for Advanced Studies, Inc.
UNC	University of North Carolina at Chapel Hill
US	United States
USPTO	United States Patent and Trademark Office

Chapter 1 Introduction

US research universities are recognized by institutional and political leaders alike for their potential ability to enhance a region's long term stability and economic growth through their technology commercialization efforts. Licensing results of academic research to industry and creating startups to further develop and commercialize early stage inventions are acknowledged by several as mechanisms both university leadership and regional policy developers consider to promote economic development (Siegel & Phan, 2005; Breznitz & Feldman, 2012; Audretsch, 2013). While considering this potential economic development impact, university administrators may be uncertain as to the optimal alignment of organizational characteristics, practices, and policies for university technology transfer efforts (Siegel & Phan, 2005) to meet strategic commercialization objectives.[1] University technology licensing offices (TLOs) are the primary unit at most US research universities tasked with providing commercialization services and support to entrepreneurial faculty, translating research results to the public, and maximizing licensing revenues for the university (Abrams, Leung & Stevens, 2009). An increased emphasis is being placed by national legislators on academic entrepreneurship and technology transfer efforts for economic development across the US, and many recommendations are being proffered to stimulate the commercialization of inventions created from publicly funded research (Wright, Clarysse, Lockett, & Knodkaert, 2007; Litan & Cook-Deegan, 2011; Merrill & Mazza, 2011). Federal initiatives are being presented to congress supporting commercialization of federally funded academic inventions and startup formation, including The

[1]The terms 'technology transfer' and 'technology commercialization' are used interchangeably throughout this document, and mean the activities engaged in by a university technology licensing office (TLO) to move academic inventions into the commercial market. TLOs act to transfer university inventions to a commercial entity, via a license to an existing firm or a university startup.

Startup Act 3.0 (H.R.714 & S.310)[2], and the Technology and Research Accelerating National Security and Future Economic Resiliency Act of 2013 (H.R. 2981)[3]. These bills propose federal funding agencies provide funds for initiatives to identify optimal technology transfer programs for replication across other universities to facilitate the transfer of commercially viable innovations developed from federal funding, including the formation of university technology licensing consortia and proof of concept centers at universities across the US. The present state of academic technology transfer capabilities at US research universities can be linked to history, culture and experience in transferring innovation to industry (O'Shea, et al., 2005); as well as a key policy development (the Bayh-Dole Act) in 1980 which allowed universities to retain title to patentable inventions sponsored by US federal funding agencies (P.L. 96-517).[4] The existing organizational cultures and characteristics when technology licensing offices TLOs are established have an influence upon subsequent structures, decisions, actions and processes (David, 1994), suggesting the early organizational structure of the TLO and other university characteristics can exert influence upon the internal technology transfer process and its outcomes.

Moving university developed innovations forward for the benefit of the public is a growing concern for federal funding agencies and academic research institutions alike; now an implicit third mission of US research institutions along with teaching and research activities (Etzkowitz, 2003; Breznitz & Feldman, 2012). This effort requires balancing both traditional roles of the university and new entrepreneurial roles (Etzkowitz et al., 2000). This expanded 3rd mission may become more

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[2]A bill "To jump-start economic recovery through the formation and growth of new businesses, and for other purposes," introduced as H.R. 714 and S. 310, Startup Act 3.0, & presented to the 113th congress February 2013 http://www.govtrack.us/congress/bills/113/hr714, and http://www.govtrack.us/congress/bills/113/s310

[3]A bill requiring each federal agency "carry out a grant program to support innovative approaches to technology transfer at institutions of higher education …, nonprofit research institutions and Federal laboratories in order to accelerate the commercialization of federally funded research..." http://www.govtrack.us/congress/bills/113/hr2981/text

[4]The Association of University Technology Managers website has a comprehensive explanation of this Act and its impact upon university technology transfer activities. See http://www.autm.net/Bayh_Dole_Act/7698.htm

important as academic universities evaluate potential for regional economic development impact through technology commercialization efforts, and look for alternative sources for research funding. In response to these initiatives and growing expectations, university leaders are evaluating existing mechanisms and processes for technology transfer to identify sources of increased efficiency and effectiveness. Key university technology commercialization mechanisms include direct licensing to existing industries, the generation of university-based startups, and research partnerships with industry and other research institutions (Phan & Siegel, 2006), all of which may result in financial gains and other benefits for the university. TLO and university characteristics, cultures, policies and expectations supportive of the technology transfer process may positively influence technology commercialization efforts in the academic environment. This dissertation project, with three separate and distinct studies, provides insight into characteristics of universities, licensing consortia, and university TLO characteristics and attributes that can influence the technology transfer processes and commercialization outcomes from US research universities.

University Characteristics and Technology Transfer

Heterogeneity in regional characteristics, university characteristics, and TLO characteristics and capabilities across US research universities have been observed by practitioners and researchers of academic technology transfer, as well as industry licensees and legislators involved in technology transfer policy development. Siegel & Phan (2005) find the effectiveness of a university's technology transfer process is influenced by competencies of university faculty inventors, licensees of university inventions or entrepreneurs forming startups, as well as business capabilities and competencies of licensing staff within the TLO, and university incentives to engage in entrepreneurial activities. The institutional and environmental characteristics in which academic technology transfer activities are carried out can influence a university's abilities in negotiating licensing agreements and forming startups (Siegel, et al., 2003; Lockett & Wright, 2005; Powers & McDougal 2003; Link & Siegel, 2005; Chapple, et al., 2005). External regional resources such as venture capital availability, and

levels of industry research and development can facilitate a university's propensity to engage in technology transfer activities and startup formation (Powers, 2003; Powers & McDougal, 2005a & 2005b). A clear university mission statement and leadership focused on the goals of technology transfer contribute to a positive entrepreneurial culture and facilitate licensing activities and licensing revenues received from technology transfer efforts (Friedman & Silberman, 2003). The propensity of faculty to disclose inventions to the TLO is influenced by several characteristics including faculty quality, research levels, and university incentive policies–specifically policies regarding university royalty and equity distribution (Renault, 2006; Markman, et al, 2004). Support from university leadership and policies in support of technology commercialization activities enable the development of an entrepreneurial culture (O'Shea, et al, 2005). Invention disclosures are a critical input into the technology commercialization process; with higher disclosures leading to increased licensing and startup activity (Siegel, Waldman & Link, 2003; Friedman & Silberman, 2003; Siegel, Veugelers, & Wright, 2007; Feldman & Berovitz, 2010; Jensen & Jones, 2011). University inventors must also have confidence in the commercialization skills and abilities of the TLO to successfully transfer their innovation to the market (McGee, 2007). Organizational practices and TLO structural characteristics, contribute to the productivity of the TLO and use of various licensing mechanisms (Feldman, Feller, Bercovitz & Burton, 2002; Siegel, et al., 2003; Markman Gianiodis, Phan, & Balkin, 2005a; Markman, Gianiodis, & Phan, 2009). Appropriate alignment of characteristics under control of the university can facilitate certain technology commercialization activities in support of the university's strategic technology transfer goals (Lockett & Wright, 2005).

TLOs facilitate commercialization of academic inventions through protection of intellectual property (via patent applications, copyrights, and trademarks), marketing the inventions and negotiating licenses with industry, and facilitating the formation of university startups (Dill, 1995; Bozeman, 2000; Lerner, 2005). The organizational structure of the TLO within the university environment and educational skills within the TLO can have an influence upon the technology

transfer process (Bercovitz, et al., 2001; Markman, Gianiodis, Phan & Balkin, 2004; Markman et al., 2005a; Markman et al., 2009). Organizational differences in these characteristics may contribute to variances in academic entrepreneurial activity and the formation of university startups across universities. As such, these specific characteristics can be evaluated for their relationship and potential influence upon the outcome metrics by which TLOs are evaluated.

The work contained in this dissertation project contributes to the growing body of literature on academic entrepreneurship and technology transfer.[5] The information provided is timely as federal discussions continue regarding efforts to stimulate the commercialization of federally funded research; and research universities across the US continue to be scrutinized and evaluated for their efficiency and effectiveness in moving academic innovations into the private sector (Litan & Cook-Deegan, 2011). The studies in this project provide information for universities or other parties that may be considering entering into partnership or consortia to facilitate technology licensing activities, or for those evaluating internal university TLO structures and knowledge skillsets for alignment to maximize technology transfer efforts. This research project on how specific university characteristics may influence the academic technology transfer process and its outcomes provides information for interested university leaders, economic development practitioners, and legislators on how university and TLO characteristics may be aligned to facilitate academic technology transfer and support efforts of entrepreneurial inventors.

Dissertation Approach

This dissertation project is designed to provide academic analysis through three different yet related research projects on academic entrepreneurship and technology transfer. The first, a literature review of specific studies on academic technology transfer, discusses the implications of findings

[5]Rothaermel, Agung, and Jiang (2007); Agrawal (2001); Djokovic, and Souitaris (2008); O'Shea, Allen, O'Gorman, and Roche (2004); Phan and Siegel (2006); Siegel (2012) and all provide comprehensive literature reviews on university entrepreneurship and technology transfer.

from these studies on drivers behind the growth in university licensing and commercialization efforts, characteristics and attributes factoring into the technology transfer process, and influencing its commercial outcomes. Findings from these groups of studies are summarized and synthesized for what they tell us of how various regional, university and TLO characteristics may factor into the academic technology transfer process, and gaps in analysis are identified for further research. The second project is a case study of an early licensing consortium between Duke University, The University of North Carolina at Chapel Hill (UNC) and North Carolina State University (NCSU) in 1988, and provides relevant background and perspective on early stage technology licensing consortia between research universities. A quantitative analysis in a third project evaluates TLO reporting structures and characteristics of TLO directors from 76 US research universities to explore possible correlations between these characteristics and academic technology commercialization outcomes. This analysis attempts to fill a gap in the literature by identifying organizational reporting structure and educational degrees of TLO directors as characteristics that guide and enhance specific activities along the technology transfer process. Each of these studies builds upon and supplements existing research on academic entrepreneurship and technology commercialization efforts.

Literature Review

The first research project in this series of studies: *University, TLO and Regional Characteristics Related to the Technology Transfer and its Outcomes–A Literature Review*, provides an introduction to key university, TLO and other characteristics shown to have an influence upon academic technology transfer. This literature review analyzes key research studies on organizational resources, characteristics, attributes and licensing practices of universities and TLOs. These studies evaluate characteristics of institutions that seem to be more effective and efficient in obtaining invention disclosures, licensing inventions to industry and generating licensing revenues, in generating startups, and in using equity with startups formed to commercialize university intellectual property (IP). Findings on the influence of various institutional, organizational and regional

characteristics are summarized and evaluated for similarities and differences, and how these characteristics are related to the technology transfer process and its outcomes. Some differences are noted for characteristics that seem to influence licensing activities versus startup formation. General conclusions are discussed, implications presented for university leadership, and gaps in the literature are identified for further analysis.

Case Study

The second research project, *Collaborative Technology Transfer: A History of North Carolina's Triangle University Licensing Consortium*, documents the history of one early stage technology licensing consortium among the three research universities situated around the Research Triangle Park in North Carolina (the Triangle). This consortium, the Triangle University Licensing Consortium (TULCO) managed technology commercialization and licensing activities for the University of North Carolina at Chapel Hill (UNC), North Carolina State University (NCSU), and Duke University (DUKE) for eight years. Founded in 1986 and active from 1988 until 1995, TUCLO's history is presented as an illustrative case study of the promise and pitfalls of a regional licensing consortium between three large research universities.

The framework for establishing, funding, and managing of TULCO is presented, as are the factors contributing to its dissolution. The culture around the Research Triangle Park at the time provides background context of a growing desire to increase university-industry interactions and transfer academic inventions to the private sector. An external consulting agency's 1986 report on technology transfer capabilities in the triangle provided recommendations; upon which the initial consortium structure was built to address this growing need. TULCO's impact on technology licensing activities at each of the three universities is reviewed, with analysis of various technology transfer activities during its operation. Funding levels, issued patents, and royalties collected by the universities during TULCO's timeframe are also presented to better understand the growing demand for technology licensing and commercialization capacity at each of the triangle universities. The

events leading up to the dissolution of TULCO are discussed, with recommendations presented for those considering similar technology licensing collaborations. Post-TULCO technology transfer activities from each of the three universities indicate increased technology licensing capacity and activity at each institution.

This case study provides examples of success factors and potential risks for any technology licensing collaboration. This study is timely – regional academic licensing consortia that combine multiple institutions' technology licensing efforts and capabilities into a single organization to increase effective transfer of academic innovations have been introduced into bills being reviewed by the US Congress (S.310, H.R.714). These policy recommendations suggest regional universities involved in licensing consortia may be more efficient at institutional technology transfer activities by combining and leveraging resources, potentially gaining economies of scale in technology licensing efforts. This case study provides timely perspective on such consortia and provides recommendations that may facilitate successful technology licensing partnerships.

Empirical Analysis

The third research project; *US University Organizational Characteristics and Technology Transfer Performance*, examines TLO organizational structure and educational background of the TLO director, as factors that may influence technology transfer outcomes from US research universities. Many previous studies examine university characteristics and relative productivity in transferring the results of research to the commercial market.[6] These studies find a number of university characteristics support successful academic commercialization efforts including: institutional culture, tradition and history; research funding levels and type; the presence of medical, engineering, or law schools; university policies and orientation in support of inventors and entrepreneurial faculty; TLO organizational structure and interaction with other academic units; as

[6]For a current thorough review of these studies, see Bradley, S. R., Hayter, C. S., & Link, A. N. (2013). Models and methods of university technology transfer. *Foundations and Trends® in Entrepreneurship*, *9* (6), 571-650.

well as characteristics of inventors and university faculty. Technology licensing office characteristics important to the technology commercialization process include the number of disclosures received; the age and size of the TLO; its financial structure; legal expenditures; cumulative experience; and prior experience. Studies evaluating these characteristics suggest that heterogeneity in these characteristics among universities can help explain why some universities seem to be more effective than others (O'Shea, et al., 2005; Siegel, et al., 2003; Feldman & Bercovitz, 2010; Jensen & Jones, 2011). This research project evaluates specific characteristics of the university TLO; organizational reporting structure, and the educational background and job tenure of the TLO director to determine their potential influence on the technology transfer process. This third research project employs an econometric modeling approach to provide statistical inference for how these characteristics are related to technology transfer outcomes.

There are different organizational structures of university TLOs identified from previous work (Bercovitz, et al., 2001; Feldman & Bervocitz, 2010) that may determine how they interact with other university functions and the availability of resources that can be leveraged for commercialization activities. The majority of TLOs report to the research function within the university, while some TLOs report directly to the leader of the institution, some to an economic development or business development office, and some report to multiple university functions. These alternate reporting structures provide an opportunity for comparison between them for their influence on the effectiveness of university technology transfer. The educational training and background of the TLO director bring additional skills to the technology transfer process that may facilitate certain activities over others. The educational degree of the TLO director is tested as a proxy for skillsets of the individual responsible for managing these activities. The findings from this empirical analysis suggest these characteristics do have an influence upon academic technology commercialization efforts, with some configurations being more effective than others.

Outline of the Dissertation

The background and context for the three research projects is presented in this introductory chapter. The following three chapters each comprise the entirety of each of the three research projects. The literature review in Chapter 2 analyzes previous academic studies on university technology transfer and entrepreneurship and the methodologies used to evaluate university and TLO characteristics. Findings synthesized and summarized for the university characteristics and attributes identified as important to invention disclosure receipt, licensing and revenue generation, startup formation and use of equity. Gaps are identified and discussed for other university and TLO characteristics unaccounted for; providing the foundation for the empirical analysis contained in Chapter 4. Chapter 3 consists of the case-study analysis of an early licensing consortium in North Carolina's Research Triangle: the Triangle University Licensing Consortium (TULCO). This case study evaluates this licensing consortium's impact upon subsequent technology licensing activities at Duke University, the University of North Carolina at Chapel Hill and North Carolina State University after the consortium's demise in 1995. The empirical study comprises Chapter 4, and evaluates TLO organizational reporting structure, educational skillsets of the TLO director, and the director's job tenure for their influence on three technology licensing metrics: invention disclosures, licenses and startups. Chapter 5 presents overall policy implications and a summary analysis of the lessons learned from these three research projects. Policy implications are reviewed; the results of the research projects contained herein may be of interest to university administrators and legislators regarding the support of academic entrepreneurship, technology transfer, and licensing efforts of US universities.

Chapter 2. University, TLO, and Regional Characteristics Related to the Technology Transfer Process and its Outcomes–A Literature Review

Introduction

US university technology transfer (TT) initiatives raise important policy issues as some university administrators expect to gain substantial financial returns from technology transfer & commercialization efforts (Friedman & Silberman, 2003); while at the same time communities and regional legislators expect local universities to have a more direct role in stimulating economic growth and job creation (Smilor & Mathews, 2004; Siegel & Phan, 2006). Federal legislation in discussion by the US Committee on Science, Space and Technology proposes to award grants to "support innovative approaches to technology transfer at research institutions," for proven technology transfer processes and efforts (H.R. 2981, 2013). The terms 'technology transfer' (TT), and 'technology commercialization,' as used in this paper refer to the process by which academic inventions are licensed to industry or to a newly formed startup for eventual commercialization; entrepreneurship refers to academic inventors actively engaged in the technology transfer process of university inventions. Invention disclosures are identified by several previous studies on academic technology transfer as a critical input into this process (Friedman & Silberman, 2003; Siegel, Waldman & Link, 2003). Thursby and Kemp, (2002) find university effectiveness in technology transfer can vary depending upon characteristics and capabilities of the university, research faculty, technology licensing office (TLO) staff, and the application of available resources. Institutional structure, organizational capabilities, and incentive policies of the university can also influence the technology transfer process and its outcomes (Feldman, Feller, Bercovitz & Burton, 2002; Siegel, Waldman & Link, 2003; Markman, Gianiodis, Phan, & Balkin, 2005a; Markman, Gianiodis & Phan, 2009). Some note the dual function of TLOs in both licensing to established firms and supporting

new startup companies to commercialize university inventions (Smilor & Matthews, 2004; Chukumba & Jensen, 2005); these two outcomes require different commercialization skills and capabilities of the licensing staff in the TLO (Siegel, Veugelers & Wright, 2007). Universities may wish to focus efforts on specific technology transfer outcomes, through direct licensing to industry or forming startup companies (or both). Understanding the characteristics that influence licensing versus startup formation will be beneficial for university administrators and policy developers working to expand university technology commercialization efforts.

This literature review synthesizes findings from a cross section of prior studies on the influence of various characteristics and attributes of universities, TLOs and their regions upon the growth of technology transfer activities and outcomes among US research universities. Findings are summarized for how university, TLO, and regional characteristics may affect the technology transfer process. The influence of these characteristics on the invention disclosures submitted to the TLO, licensing outcomes, and the formation of university startups is synthesized from this body of literature. Findings suggest universities with strong capabilities in startup formation may be different from those who have success in generating large revenues from licensing. Royalty rich TLOs who have significant past success with licensing may be locked into direct licensing and may not have much success with startup formation, potentially viewing that commercialization path as a last resort (Chukumba & Jensen, 2005, p. 18). The academic technology transfer studies in this literature review come from a variety of journals dedicated to the study of academic technology commercialization efforts and startup formation, including several studies identified from the *Journal of Technology Transfer*, a special edition from *Research Policy (The Creation of Spin-off Firms at Public Research Institutions: Managerial and Policy Implications)*, *The Journal of Economics and Innovation of New Technologies*, and the *Oxford Review of Economic Policy-Intellectual Property Edition, 2007*. Other journals include the *Journal of Business Venturing*, *The Journal of Management Studies*, and *Management Science*. The highlighted studies in this literature review evaluate characteristics of US

research universities and their TLO offices, and are synthesized for their findings and how they inform the study and practice of academic technology transfer.

Examples of some case studies, benchmark studies, and efficiency studies that examine the growth and relative performance of university technology transfer functions over time are evaluated as a starting point. These studies identify characteristics of universities and TLOs that contribute to the growth and overall effectiveness of the academic technology transfer process. The first section of this review summarizes the general findings of these studies, including best practices and characteristics contributing to nominal and total factor productivity growth in university technology transfer. These studies provide background on factors driving university involvement in commercialization of university inventions (Smilor & Matthews, 2004), and describe aspects of the technology transfer process in US research universities.

Research identifying characteristics influencing (a) invention disclosure submission to the TLO, (b) facilitating licensing activity and licensing revenue, and (c) startup formation and use of equity as a licensing mechanism are each examined in subsequent sections. Invention disclosures are identified as a critical input to the technology transfer process and the level of invention disclosures coming into the TLO have a strong influence on both licensing and startup activity (Siegel, et al., 2003; Jensen & Jones, 2011). We summarize findings from several studies on various characteristics that are related to the flow of invention disclosures to the university TLO. Outcomes from university technology transfer can fall into two general categories: licensing activities, with subsequent licensing revenues; and startup formation with possible use of equity as a licensing mechanism for startups. Findings are summarized on various university and TLO characteristics that have an influence upon these outcomes. The results from these studies are compared and contrasted to evaluate the relationships discovered between characteristics and outcomes, differences in findings are evaluated for possible explanation. A discussion section summarizes the key findings from this body of literature. Findings are reviewed for overlaps and conflicts, and gaps are identified for future research.

The general managerial conclusions from this literature review and their potential policy implications are presented in a final section.

Benchmarking and Growth in Technology Transfer

Efficiency studies, surveys, case studies and benchmark comparative studies provide mechanisms for universities to evaluate their technology transfer activities relative to their peers, and identify best practices in university technology commercialization efforts. Thursby and Kemp, in their 2002 study, "Growth and Productive Efficiency of University Intellectual Property Licensing," evaluate various university characteristics to identify the drivers behind the increasing levels of technology licensing efforts at US research universities. Using data envelope analysis (DEA) combined with quintile and logistic regression analysis, the authors examine overall productivity changes in invention disclosure, patent applications, industry sponsored research agreements, license agreements, and royalty payments for 57 research universities from 1991 to 1996. The DEA method creates an efficiency frontier maximizing a ratio of multiple resource inputs to multiple outputs. Universities are partitioned into quintiles by their input and output measures, allowing comparisons of efficiency between universities of similar size; finding smaller schools and larger schools tend to be more efficient on a number of dimensions than larger schools, with higher efficiency ratios for their use of resources for TT outcomes. Logistic regression tests the influence of various characteristics for universities defining the efficiency frontier with highest efficiency ratios. Efficiency is significantly influenced by TLO size, federal funding, faculty size, and faculty quality. Quality of engineering faculty members and size of bioscience faculty positively influence a universities efficiency levels. Private universities may be up to four times more efficient than public, while the presence of a medical school somewhat reduces efficiency scores. The study attributes an observed growth in licensing to a changing entrepreneurial culture and increasing interactions with industry. The use of the DEA method in this study to identify efficient universities is problematic due to the method's highly deterministic nature and its susceptibility to outliers and noise in the model. Noise may reflect

other university characteristics that cannot be measured and may over-estimate, or under-estimate efficiency. The dichotomous variable created for efficient universities used in the logistic regression is evaluated in the study using the same input and output variables used in generating the frontier, potentially introducing serial correlations and endogeneity into the analysis, introducing concerns regarding statistical inference.

A growing receptiveness to both technology transfer and entrepreneurship is considered one of the primary drivers for growth in academic commercialization activities. In their 2002 study, "Who is selling the Ivory Tower? Sources of Growth in University Licensing," Thursby & Thursby (2002) evaluate data between 1994 and 1998 from 64 universities, and a survey of 112 licensees and industry sponsors of university IP. They evaluate growth in invention disclosure, patenting and licensing activities at US universities, using DEA to create three 'best practice frontiers' of universities with the highest ratios of resource inputs for three outcome measures: disclosures, patents, and licenses; and evaluate growth rates. TLO size, prior federal and industry research funding levels, and faculty size are used as inputs for disclosures; then disclosures, TLO size, and faculty quality are used as inputs for patents; and finally, disclosures, patents, TLO size and faculty quality are used as inputs for licenses. This study finds universities have seen nominal growth in all activities over the 5 year period; invention disclosures grew by 7.1%, patents by 17.1%, and licenses by 8.4%. Annual total factor productivity (TFP) growth rates increased for disclosures (2.7%) and patent applications (12.1%), but decreased for licensing (-1.7%); this decreased TFP may potentially be due to the time lag between initial invention disclosure and final license (Thursby & Thursby, 2002). Logistic regressions are also used to evaluate the relationship between the nominal growth rates and annual total factor productivity, including TLO growth in the regression evaluating licensing activity. The study finds higher patenting levels and increases in the size of the TLO have a negative relationship with licensing TFP, indicating universities may be 'deep-diving' and patenting inventions that have marginal commercial value to industry (Thursby & Thursby, 2002). The negative relationship

between growth in the TLO and licensing efforts suggests there may be a steep learning curve in developing skills required by TLO licensing professionals (Thursby & Thursby, 2002). In their survey analysis, industry research sponsors and licensees identify low cost of university research and growing faculty acceptance of industry supported research as important factors in the growth of industry research contracts with universities. Overall growth in academic acceptance and university leadership orientation toward technology transfer are identified as primary factors related to technology licensing growth (Thursby & Thursby, 2002). Decision envelope analysis (DEA) uses multiple inputs and outputs to create an efficiency ratio, allowing universities to benchmark themselves against peer institutions. The deterministic nature of DEA is incapable of distinguishing between random noise and true sources of inefficiency, so may not provide a true value. Multicollinearity and omitted variables can be problematic in the use of DEA, so while this method measures efficiency via an input/output ratio; it could be overlooking other characteristics that are influencing the technology transfer process.

Organizational practices in university management and commercialization of intellectual property can also influence the performance of university technology commercialization efforts. Identifying and measuring those practices sheds light on their influence. A study by Siegel, Waldman & Link (2003), "Assessing Impact of Organizational Practices on The Relative Productivity of University Technology Transfer Offices," evaluates university productivity in technology licensing activities from 80 universities from 1991-1996. This study uses ordinary least squares (OLS), stochastic frontier estimation (SFE), and qualitative field research interviews. Fifty-five interviews with university technology transfer stakeholders: business entrepreneurs, university administrators and university scientists, identify critical environmental and organizational characteristics that may influence licensing and licensing revenues of a university. SFE, similarly to the DEA method, provides a measurement of the relative productivity of each university in licensing activities and revenue generation. SFE utilizes maximum likelihood to estimate the parameters of the stochastic

frontier and a vector of potential technical inefficiency sources simultaneously, allowing hypothesis testing and construction of confidence intervals. The study uses several characteristics identified from their qualitative interviews (Siegel, et al., 2003), distinguishing these characteristics from random noise. Invention disclosures, size of the TLO, and external legal expenditures are used as inputs; licenses and licensing revenues are outputs from this efficiency model. This study finds the size of the TLO has a positive influence upon licensing activity, but is not significantly related to licensing revenues. Findings indicate external legal expenditures of the TLO have a negative influence upon license agreements, but a positive influence on revenues, suggesting legal wrangling or risk adversity may have a negative influence on license negotiations (Siegel, et al., 2003), but may be effective in garnering higher royalty streams. Environmental and institutional determinants of inefficiency include indicators for public universities and the presence of a medical school, the age of the TLO, in addition to regional characteristics such as industry R&D intensity and annual state GDP. Older TLOs are somewhat more efficient at revenue generation, which may be indicative of the time lag between finalizing a license and royalty income, or of cumulative effects from prior licensing efforts. Indicators for the presence of a medical school and for public institutions are statistically insignificant. Any precision of SFE methods is highly dependent on the number of universities in the analysis used to project the frontier, and while production functions fit well with the data, institutional inefficiencies in academic technology transfer activities cannot be completely explained by environmental and institutional characteristics (Siegel, et al., 2003). The qualitative research from interviews reveals other characteristics that might negatively influence academic technology transfer activities: insufficient faculty rewards, a lack of resources and staffing commitment to the TLO, cultural barriers, and administrative bureaucracy. A lack of marketing or technical skills in the TLO and low salary compensation for TLO professionals are also suggested as potential barriers (Siegel, et al, 2003); however there is no operationalization of these potential barriers, providing opportunities for evaluation by others who are able to capture a way to measure these characteristics.

A recent study evaluates whether the 50% growth in government research funding from 1998 to 2008 corresponds to increased efficiency in academic technology transfer activities (Kim, 2013). This study, "The Ivory Tower Approach to Entrepreneurial Linkage: Productivity Changes in University Technology Transfer," uses the DEA method to evaluate panel data from 90 US research universities using invention disclosures, TLO licensing staff, and research expenditures as input factors to determine relative efficiencies between universities and overall growth in US issued patents, licenses, and revenue. This study finds an upward trend in overall efficiency of US research universities; with an average TFP growth of 31% over the nine years, providing some evidence that universities have developed effective strategies to leverage resources for TT efforts. Licenses grew an average of 4% each year and licensing income about 28%. Inputs increased over time as well: research expenditures grew about 8.3% per year, invention disclosures grew by about 7.5% each year, and licensing staff grew an average of 11% per year, indicating growing commitment to university technology transfer. This study finds the presence of a medical school has little impact on higher TLO productivity, and no significant difference in productivity between public and private institutions, possibly due to an increased prioritization of technology transfer and commercialization across all universities (Kim, 2013). As with other studies utilizing DEA, university annual productivity data is quite volatile; universities have yearly fluctuation in efficiency measures, potentially due to the time lags between disclosure of the invention and licensing. Endogeneity concerns are a problem if productivity is measured by numerous input variables that may be highly correlated (Kim, 2013). This production function methodology is useful however, in looking at aggregate growth or decline in university technology transfer outputs over several years, and in benchmarking techniques for universities who evaluate themselves relative to their peers.

Comparative analytic methods identifying best practices from five universities known to have strong technology transfer programs and a significant influence upon regional economic development provide benchmarks for other institutions. Smilor & Matthews, in their 2004 qualitative study,

"University Venturing: Technology Transfer and Commercialization in Higher Education," compare and contrast university policies, roles of university leadership, incentives for faculty inventors, and use of equity in licensing from five institutions (Georgia Tech, North Carolina State, University. of Florida, University of Texas at Austin, and Virginia Polytechnic Institute), identifying factors that influence technology transfer and commercialization activities (Smilor & Matthews, 2004). Interviews with university representatives and technology transfer professionals provide data on organizational support for technology transfer and commercialization efforts, in addition to faculty incentive structures that support entrepreneurial behavior. Institutional characteristics, royalty distribution policies, promotion and tenure metrics, leadership support, and TLO commercialization skillsets are evaluated to determine how these characteristics support the technology transfer process (Smilor & Matthews, 2004). Strong support from university leadership in policy and practice, unequivocal support for a properly resourced TLO, and incentive systems designed to support entrepreneurial faculty are all identified as important characteristics at each of the five universities. The dual focus of the TLO: generating startups and licensing inventions requires alignment with appropriate skill sets (Smilor & Matthews) to fit with these differing commercial paths. The university TLO may benefit from staff with knowledge of university research, business commercialization skills, and links to bus development organizations to help facilitate startups and provide resources beyond the capabilities of the TLO and the university.

Summary

Several key characteristics are identified as factors related to the technology transfer process from these studies on university effectiveness in technology commercialization. Thursby and Kemp (2002) note university productivity varies with capabilities of TLO staff and research faculty, as well as the use of university resources, suggesting that the efficiency of universities in technology commercialization is not necessarily deterministic and may depend upon the environment in which it is carried out. An entrepreneurial culture, support from leadership, quality of research faculty,

research funding levels, and size of the TLO are identified as characteristics that influence technology transfer. Each study notes the importance of an entrepreneurial culture and support from university leadership. Invention disclosures are a critical input into the technology commercialization process, and have a significant influence on both licensing activities and licensing revenues (Siegel, et al., 2003). Private universities are more efficient that public universities in one 2002 study (Thursby & Kemp, 2002), while subsequent studies show no difference between public and private institutions (Siegel, et al, 2003, Kim, 2013). The presence of a medical school has a negative relationship with the likelihood of a university being on the efficiency frontier in Thursby & Kemp's (2002) study, even though many licenses are for biomedical inventions; authors suggest this relationship may be due to heavy service commitment of medical schools rather than commercialization (Thursby & Kemp, 2002). Quality of the engineering faculty and size of the bioscience faculty also have a positive influence on technology transfer efforts in Thursby & Kemp's (2002) study. University TLOs have grown as there has been an increased resource commitment to technology transfer and faculty entrepreneurs (Kim, 2013). Findings on TLO size vary: larger TLOs are more effective in revenue generation, but less effective at licensing activities in one study (Siegel, et al, 2003). Another study finds growth in a university TLO reduces efficiency levels for commercialization outcomes, potentially due to steep learning curves of new licensing staff (Thursby & Thursby, 2002). Business skills are noted as important in two of the qualitative analyses (Siegel, et al., 2003; Smilor & Matthews, 2004), suggesting the commercialization skills of the licensing staff may be a characteristic for further exploration. TLO age has a positive relationship with revenues, somewhat expected due to time lags between invention disclosure, licensing, and receipt of revenues (Siegel, et al., 2003). Regional research and development levels in Siegel, et al.'s (2003) study have a positive relationship with university licensing activities, suggesting universities situated in areas with higher levels of industry R&D may have more opportunities for licensing. Table 2.1 summarizes the findings

from this select group of studies on efficiency and best practices of US universities in technology transfer.

Table 2.1 Characteristics of Efficiency and Effectiveness in Technology Transfer

University Characteristics			
Characteristic	Study	TT Outcomes	Finding
Private	Thursby & Kemp (2002)	Disclosures, patent apps, industry research licenses, & revenue	Private may be 4X more efficient than Public Universities
	Kim (2013)	Issued US patents, licenses, and revenue	No significant difference in productivity
Public	Siegel, et al. (2003)	Licenses and revenues	No significance for public indicator on licenses and revenues
Medical	Thursby & Kemp (2002)	Disclosures, patent apps, industry research licenses, & revenue	The presence of a medical school has a negative influence upon efficiency scores in logistic regression
	Siegel, et al. (2003)	Licenses and revenues	No significance for medical school indicator on licenses and revenues
	Kim, (2013)	Issued US patents, licenses, and license income	Presence of a medical school has little impact on higher productivity of licenses & licensing income
Federal research funding	Thursby & Kemp (2002)	Disclosures, patent apps, industry research licenses, & revenue	Slight significance for federal res funding levels when environ characteristics (private & medical school) are included
Entrepreneurial policy orientation	Thursby & Kemp (2002)	Disclosures, patent apps, industry research licenses, & revenue	Expanding entrepreneurial culture, increased willingness of faculty to disclose, & university to apply for patents drive TT activities
	Thursby & Thursby (2002)	1. Disclosures; 2. Patent applications; 3. Licenses;	Growth in TT comes from increasing entrepreneurial culture and willingness of faculty to disclose. Growth in patenting has not seen corresponding growth in licensing.
	Siegel, et al. (2003)	Licenses and revenues	Barriers to TT: lack of faculty rewards, compensation & staffing of the TLO, cultural, & administrative bureaucracy
	Smilor & Matthews (2004)	TLO (budget, staff, $, #licenses, #startups, equity use) Royalty distribution	Strong support from leadership, unequivocal support for TLO, & incentive systems designed to support entrepreneurial faculty positively influence TLO outcomes
Faculty quality	Thursby & Kemp (2002)	Disclosures, patent apps, industry research licenses, & revenue	National Research Council (NRC) rankings: Quality of engineering faculty positive influence upon efficiency
Faculty size	Thursby & Kemp (2002)	Disclosures, patent apps, industry research licenses, & revenue	Size of biological faculty present at university has positive influence on TT outcomes

Table 2.1 (*continued*)

TLO Characteristics			
Characteristic	Study	TT Outcomes	Finding
Disclosures received by TLO	Siegel, et al. (2003)	Licenses and revenues	Critical input: strong positive influence on licensing and revenue Engagement of TLO with faculty significantly influences disclosure rate
Size of TLO	Thursby & Kemp (2002)	Disclosures, patent apps, industry research licenses, & revenue	Larger TLOs more inefficient in all TT outputs
	Siegel, et al. (2003)	Licenses and revenues	Significant influence on increased licensing, not revenues
	Kim (2013)	Issued US patents, licenses, and license income	Licensing staff grew an average of 11%/year '98-'08, indicating growing commitment of university resources
Age of TLO	Siegel, et al. (2003)	Licenses and revenues	Older TLOs have significant influence on increased revenues, not licensing
External legal expenditures of TLO	Siegel, et al. (2003)	Licenses and revenues	External legal costs have a positive influence on revenues, and a negative influence upon licensing agreements
Business skills	Thursby & Thursby (2002)	1. Disclosures; 2. Patent applications; 3. Licenses;	Rapidly expanding TLO = lower productivity due to steep learning curves of new hires
	Siegel, et al. (2003)	Licenses and revenues	Qualitative research: lack of marketing or technical skills in the TLO, and low salary compensation are identified as potential barriers
	Smilor & Matthews (2004)	TLO (budget, staff, $, #licenses, #startups, equity use) Royalty distribution	Dual focus of the TLO requires alignment with appropriate skill sets to increase commercialization outcomes Links to business resources are key.
Regional Characteristics			
Characteristic	Study	TT Outcomes	Finding
Regional Industry R&D	Siegel, et al., (2003)	Licenses and revenues	Level of industry R&D in state has a positive influence upon licensing activity of universities

Disclosure Submission

Invention disclosures from research faculty are a critical input into the technology transfer process; previous studies find invention disclosure receipt by the university TLO influences all subsequent technology commercialization efforts (Friedman & Silberman, 2003; Siegel, Waldman & Link, 2003; Chukumba & Jensen, 2005; Jensen & Jones, 2011).Universities with more experienced TLOs, incentive policies for inventors, and strong entrepreneurial culture are likely to have higher

invention disclosures from research faculty. Siegel, Waldman & Link (2003) find invention disclosures received by the TLO to be a critical input into the technology transfer process, and are significantly and positively related to both licensing and licensing revenue. Higher disclosure rates can lead to (a) more licenses, (b) execution of more licenses with equity interests (Friedman & Silberman, 2003), (c) higher licensing revenues (Siegel, et al., 2003), and (d) the formation of more university startups (Jensen & Jones, 2011). Determining characteristics of universities and TLOs that have high rates of invention disclosures provide information relevant to those wishing to encourage disclosure from research faculty. Several studies analyze the disclosure of inventions to the TLO as part of their overall analysis of the technology transfer process, these findings help identify characteristics of universities, university faculty, and TLOs related to high disclosure rates, which provide increased opportunities for licensing and startup formation.

In the efficiency benchmark studies discussed above, Thursby and Thursby (2002) find invention disclosure rates increasing by 7.1% from 1994 to 1998. This study attributes growth in the propensity of faculty to disclose their inventions to growing cultural acceptance and previous licensing success by the TLO. The study finds growth in invention disclosure submission is primarily driven by an increased receptiveness of faculty to disclose results of their research rather than a reorientation of research interests away from basic research towards applied research (Thursby & Thursby, 2002). In interviews with key technology transfer stakeholders, including entrepreneurs, TLO directors, and university scientists, Siegel, et al, (2003) identify relationship building as an important element of the technology transfer process, and the TLO licensing individuals as key to facilitating relationships between research scientists and licensees. Building relationships with research scientists can influence their participation in the technology transfer process starting with submission of invention disclosures; facilitating relationships between university research scientists and industry licensees expedite the transfer of technology from the university (Siegel, et al, 2003). Thursby and Kemp (2002) find that universities most efficient in obtaining invention disclosures fall

in the largest and smallest of the five quintiles in their comparison groups among peer universities, suggesting the largest may have higher faculty engagement in the technology transfer process requiring less outreach of the TLO, and smaller universities may be able to directly engage with research faculty to build relationships, positively influencing invention disclosure rates.

Friedman & Silberman, in their 2003 study, "University Technology Transfer: Do Incentives, Management and Location Matter?" evaluate data from 93 research universities from 1997 to 1999, and find several university and faculty characteristics influence invention disclosure submission to the TLO. A two equation OLS regression recursive system models the technology transfer process of the university as a sequence of events, and identifies invention disclosure from research faculty as a critical "raw input" to the technology transfer process (Friedman & Silberman, 2003, p.21). Invention disclosures are modeled in the first regression, finding faculty quality, the number of science departments offering a PhD degree (as determined by the National Research Council - NRC), and levels of federal and industry sponsored research all have a positive influence on invention disclosure submission. The estimated invention disclosures are subsequently utilized in several second stage regressions as an independent variable to analyze characteristics influencing licensing activity, licensing income, the number of startups, and use of equity in licensing deals. The findings for these outcomes are further explored in the sections below. There are some limitations to this study including a relatively high correlation among the independent variables in the equation modeling invention disclosures; faculty quality, federal research funding, and industry research funding are all highly correlated with each other (>0.7). The endogeneity and multicollinearity of these variables are likely influencing each other, introducing potential bias and making causal determinations difficult (Friedman & Silberman, 2003). An alternative measure may be the use of a ratio of industry to federal funding to remove the correlation problem with using both funding variables.

A study by Thursby and Thursby (2007), "University Licensing," evaluates the rationale behind university licensing activities, looking at the stage of technologies being licensed, the

relationship between university characteristics and licensing revenue, and the propensity of faculty to disclose to the university TLO. This study combines OLS regression, logistic regression and qualitative interviews to evaluate university technology commercialization, and to evaluate whether research faculty are diverted from basic toward applied research. For invention disclosure from faculty, the study utilizes logistic regression to evaluate the propensity of faculty disclosure to the TLO modeled as a function of university and inventor characteristics. This study finds the scientific background of the inventor can have an influence upon disclosure rates; inventors with an engineering background are more likely to disclose inventions to the TLO, and bioscience faculty least likely to disclose. Quality measures such as high publication rates and high levels of both federal and industry research funding increase the likelihood of disclosure. Industry funding may have twice the influence on disclosure rates compared to federal research funding, possibly due to the more applied nature of industry funding creating outcomes with commercial value (Thursby & Thursby, 2007). The study finds little evidence that faculty are being diverted from basic research; changes in publication rates show no substantial shift towards applied research despite the positive influence of industry research funding on invention disclosure rates (Thursby & Thursby, 2007).

Summary

The studies summarized herein find that invention disclosure submission to the university TLO can be influenced by different characteristics of the university, its faculty, and of the TLO itself. University characteristics influencing disclosure rates include the university's culture and support for entrepreneurial activities, which can facilitate disclosure from faculty as the critical first step in the technology transfer process (Thursby & Thursby, 2002). The growing willingness of universities to invest in commercialization of research-based inventions through intellectual property protection, marketing and licensing have facilitated the development of entrepreneurial cultures at research universities. Federal and industry funding levels for research, and the relative number of science departments university with graduate programs can also influence disclosure rates (Friedman &

Silberman, 2003), as do various aspects of faculty quality, including publication rates, individual funding levels, and scientific background (Thursby & Thursby, 2007). TLO engagement with research faculty can also have a strong positive influence upon invention disclosure submission through relationship building (Siegel, et al, 2003), suggesting the networking and commercialization skills with the TLO are important to this critical input to the technology commercialization process. Table 2.2 summarizes the findings on characteristics identified as influencing invention disclosure submission at US research universities.

Table 2.2 Characteristics Influencing Invention Disclosure

University Characteristics			
Characteristic	Study	TT Outcomes	Finding
University support/ Policy orientation	Thursby & Thursby (2002)	DEA: 3-stage process 1st Disclosures Qualitative Survey, N=112 licensees	7.1% growth in disclosures; influenced by increased propensity for faculty to disclose, facilitated by university willingness to support & patent IP
Federal & industry research funding	Friedman & Silberman, (2003)	Disclosures (ID) '97-99	High levels of federal and industry funding has a strong positive influence on invention disclosures to the TLO
University size	Thursby & Kemp, (2002)	Disclosures	Smallest and largest universities are more efficient in obtaining disclosures than mid-size universities
University size	Friedman & Silberman (2003)	Disclosures (ID) '97-99	Universities with more science departments offering a PhD have higher rates of disclosure submission
Faculty quality	Friedman & Silberman (2003)	Disclosures (ID) '97-99	NRC faculty quality index highly correlated with invention disclosure
Faculty quality	Thursby & Thursby, (2007)	Probability of Faculty Disclosure	Faculty publication rates positively correlated with disclosure; engineering faculty more likely to disclose than bioscience; more research funding leads to more disclosures; industry funding has about 2X impact of federal
TLO Characteristics			
Characteristic	Study	TT Outcomes	Finding
TLO engagement with faculty	Siegel, et al. (2003) (Qualitative interviews)	Licenses and revenues	Engagement of TLO with faculty encourages disclosure rate, a critical input and strong positive influence for licensing activities and revenue

Licensing Activities & Licensing Revenues

License agreements with industry are one of the primary outcomes from the university technology transfer process, and effectively transfer the commercialization rights of the IP to the industry partner, who is responsible for further development, marketing and selling the IP. One measure of success for this particular activity is royalty revenues received from licensees who are successful in commercializing university inventions. Several studies analyzing licensing efforts and licensing revenue as outcomes of the technology transfer process find the probability of licensing success depends upon various attributes of the university, the TLO, the inventor, and licensees of university intellectual property. Shifts in university policies can enhance the entrepreneurial culture of the university, positively influencing invention disclosure to the TLO (Powers & McDougall, 2005b), and increase the pool of inventions available for licensing (Chukumba & Jensen, 2005). University characteristics related to licensing efforts of US universities include institutional characteristics such as public or private institutions, the presence of a medical school, levels of federal and industry research funding, university policies in support of academic entrepreneurship, revenue sharing percentages with inventors, and quality of faculty engaged in the technology transfer process. TLO characteristics that can influence licensing activities and revenues include the structure of the TLO, age and experience level, and business & commercialization capabilities. Findings from several studies on licensing efforts of universities provide a comprehensive picture of the various university, TLO, and regional characteristics that can influence licensing efforts of US universities.

In a two equation recursive system, Friedman & Silberman (2003) find several characteristics that can factor into licensing activities and licensing revenues at a university, the most important being the number of invention disclosures in the technology transfer pipeline. Invention disclosures received for the three years prior show a strong positive influence upon licensing activity in 1999 (Friedman & Silberman, 2003). This study includes institutional indicators for private versus public institutions, the presence of a medical school, and whether the institution is land grant; finding no

significant influence of these institutional characteristics on licensing activities or licensing revenues. University policies in support of academic entrepreneurship can have a direct impact on licensing activities: a higher royalty sharing percentage with an inventor's department is negatively related to the number of license agreements, while a higher royalty sharing percentage with inventors is positively related to licensing revenue (Friedman & Silberman, 2003). The study also finds older, more experienced TLOs are more likely to have higher rates of licensing and licensing revenues. Using a two-stage recursive OLS model, their method is unable to control for any nested interactions of these characteristics; suggesting a hierarchical modeling technique might be helpful in evaluating the different commercialization outcomes simultaneously. Use of ratios rather than both federal and industry funding measures which can be highly correlated with each other may help address any multicollinearity issues biasing results.

Chukumba and Jensen, in their 2005 study, "University Invention, Entrepreneurship and Start-ups," evaluate characteristics related to inventor quality, the research environment of the university, and the environment of the TLO on the ability to license inventions to existing firms. Their study uses a negative binomial regression method, useful for data in count form with a high number of zeros and over dispersion, to examine characteristics and attributes of 110 universities. This study finds successful licensing is more likely with higher inventor quality, experienced TLOs, and inventions with lower costs of development (Chukumba & Jensen 2005). Indicators for the presence of a medical school and private institutions are not significant, while the percentage of industry funding of total research has a positive relationship with licensing activities. Chukumba & Jensen (2005) provide strong evidence that inventor quality, (as determined by NRC rankings) is positively related to success in licensing activity, particularly that of engineering faculty. The age of the TLO (as a proxy for experience and expertise) is strongly correlated with increased licensing activities, while the size of the TLO is not found to have significant influence. The numbers of disclosures received by the TLO and royalty income from previous successful licenses have a positive

influence with current licensing efforts, suggesting a large pipeline of invention disclosures and previous success in licensing university inventions create a positive entrepreneurial culture.

Commercialization speed can also be a significant influence on successful licensing and royalty generation from academic technology transfer activities. Markman, Gianiodis, Phan and Balkin (2005a) in their study, "Innovation Speed: Transferring University Technologies to Market," find TLOs that are successful in quickly moving university inventions to commercialization have higher licensing revenues. Their study evaluates characteristics of 91 universities using speed of technology commercialization as a mediator to licensing revenues and new venture formation, focusing on the importance of faculty inventors, the degree of collaboration, and the competency of the TLO on the receipt of licensing revenues. Hierarchical linear regressions allow modeling to evaluate the mediating effects of time to commercialization, providing a mechanism to investigate commercialization speed as exogenous to technology transfer outcomes. University and TLO characteristics also include indicators for public institutions, the age and size of the TLO, and TLO structure. The study finds public universities generate less licensing revenues than private universities; and the size of the TLO has a positive influence on revenue generation, while no significance is found for TLO age (Markman, et al, 2005a). TLO structure, defined as either a) Traditional (an internal unit of the university), b) Non-profit (external to the university, such as a research foundation), or c) For-profit (with a venture arm focused upon startup creation), can also have an influence upon licensing activities and licensing revenues (Markman, et al, 2005a). Traditional TLO structures generate less revenue than non-profit or for-profit structures; however TLO structure is not significantly related to commercialization time in licensing. Determinants of commercialization time include collaboration complexity involved in the creation of the invention, TLO competencies (number of industry contacts to license), and faculty involvement. The study finds inventor-initiated licensing marginally reduces time to commercialization and the number of inventors from other universities contributing to an invention increases time to direct licensing

(Markman, et al, 2005a). Business skills within the TLO can have an impact upon commercialization speed, a lack of business competencies (# of contacts to license) increases commercialization time, which has a negative influence on licensing revenues. Early stage limitations posed by inventor-related impediments such as resistance, indifference, and poor-quality disclosures increase time to commercialization, while later in the commercialization process the number of external inventors and lack of business competencies of the TLO significantly increases time to licensing (Markman, et al., 2005a). These findings suggest time to commercialization is significantly related to technology transfer outcomes, with increased speed a strong positive influence on licensing revenues.

University policies in support of the technology transfer function can interact with regional characteristics to influence licensing and licensing revenues. In their study, "Policy Orientation Effects on Performance with Licensing to Startups and Small Companies," Powers and McDougall (2005b) compare interactions of institutional policies and attributes with regional entrepreneurial density characteristics on licensing revenues and IPO events for 134 US universities from 1999-2000. A hierarchical moderated regression approach evaluates the potential influence and interactions between selectivity policies of the university oriented toward startup and small business licensing, support for the TLO, and regional entrepreneurial density on a variety of technology transfer outcomes. The hierarchical method allows the evaluation of university and TLO characteristics in their nested environments, and of any interactions between them. Statewide research & development activity, number of patents per state, venture capital investment levels, and SBIR & STTR grants provide measures for a combined regional entrepreneurial density characteristic, but findings indicate entrepreneurial density has little influence upon licensing revenues of the university. The potential interactions between startup selectivity policies and entrepreneurial density are not a significant influence on revenues; however the interaction of commercialization strategies oriented towards startups with large resource commitment to the TLO can have a negative influence on licensing revenues (Powers & McDougall, 2005b). The age of the TLO provides a proxy for licensing

experience; university characteristics include faculty quality measures (from the 1997 Gourman rankings of graduate programs), and the presence of a medical school. Faculty quality and the age of the TLO have a positive influence on licensing revenues, and the presence of a medical school is not significantly related to licensing revenues. Capturing regional entrepreneurial densities by state may overlook metropolitan areas that cross over state boundaries, utilizing metropolitan statistical area (MSA) regional variables for entrepreneurial characteristics may be an appropriate alternative, as noted by the authors (Powers & McDougall, 2005b). This study finds a university's policy orientation for licensing and startup formation should be developed in consideration of regional entrepreneurial characteristics that may support technology transfer from the university.

Licensing revenues received by universities are indicators of some level of success in the technology transfer process, as licensing income indicates the university invention has reached its commercial application. Characteristics of universities, TLOs and inventors that may have an influence upon licensing revenues are analyzed by Thursby & Thursby (2007), in their study, "University Licensing." This study utilizes OLS regressions to evaluate relationships between university and TLO characteristics and the licensing revenues received for 148 universities in 2004. Characteristics include TLO age, the number of current licenses generating income, the size of the TLO, and research funding levels. Their study finds research funding levels have a strong significant relationship with licensing revenues, indicating larger research institutions may have greater success in licensing inventions. The number of TLO licensing personnel, and prior experience and success in licensing, measured via the number of licenses currently generating income all have a strong positive correlation on revenues received by the universities in 2004. The study logs all variables to control for non-linearity in the data, and OLS provides measures of strengths of relationships, without pointing to a causal influence.

The impact of TLO licensing strategies, TLO structure and payment contracts with inventors, their departments and licensing personnel are analyzed for their influence on licensing revenues by

Markman, Bianiodis, and Phan (2009) in their study "Supply-Side Innovation and Technology Commercialization," for 128 US research universities from 1999-2002. This study utilizes a hierarchical regression method to model the university TLO as a supplier of innovation to industry, controlling for institutional characteristics, including the age and size of the TLO, indicators for public universities, faculty quality measures and the presence of a university affiliated incubator in the first stage of their hierarchical regression. Outcomes are log-transformed to control for non-linearity in the data. Second stage regression includes characteristics of TLO licensing strategies (licensing for sponsored research versus licensing for cash), TLO structure (low versus high autonomy), and university incentive policies in the form of percentage sharing of revenues with inventors and their departments, and TLO salaries (Markman, et al., 2009). This study finds the size of the TLO and faculty quality are related to licensing revenues in the initial regression, with public universities generating less revenues than private universities. Both licensing for sponsored research and cash licensing are indicated as having a negative influence on licensing revenues, suggesting TLOs focused upon sponsored research or upfront cash licenses may under perform their peers in collecting revenues from licensing activities (Markman, et al., 2009). A focus upon cash licensing may reflect university administrative expectations of the TLO to become self-sustaining, but a predominant focus upon short-term funding may have a negative influence on overall revenue generation in comparison to a more balanced licensing strategy. TLO structural autonomy, categorized as low (constrained by centralized university policies) or high (decentralized, with freedom to negotiate terms based upon market dynamics) can influence revenues, with TLOs categorized as low autonomous structures having a negative influence upon revenues received from 1999-2002, suggesting centralized university control over the TLO may deter the TLO from creative licensing efforts. Findings suggest licensing strategies of university TLO may benefit from a mixed approach for determining payments from licensees, and may benefit from less centralized control over the TLO. Findings for incentive policies for inventors suggest a negative influence between

percentage sharing with inventors and overall revenues, while payments to inventor departments have an overall positive influence on revenues. TLO salary levels of licensing professionals are not significantly related to licensing revenues. Larger TLOs and faculty quality are positively related with revenues, while public universities receive less revenue than private institutions (Markman, et al., 2009). This study finds characteristics of the TLO in organizational structure and licensing strategies can have a strong influence upon licensing revenues received from the technology transfer process.

Bulut and Moschini (2009) in their study "US Universities' Net Returns from Patenting and Licensing: A Quantile Regression Analysis," also evaluate returns, or net revenues received by 148 universities from 1998-2002 from licensing efforts, evaluating basic institutional characteristics such as indicators for public/private institutions and the presence of a medical school, and levels of research expenditures. Data come from AUTM licensing surveys, calculating net revenues as royalties with deductions for external legal expenditures. This study uses OLS and quantile regressions on averages of all time varying variables to determine the influence of institutional characteristics on net revenues received from licensing activities. Indicators for private institutions and medical schools are interacted with each other to determine how the interaction of these two institutional characteristics might influence licensing revenues. Quantile regressions divide the 148 institutions into six equal groups, and allows the estimation of the maximum revenues a university might gain at a given probability level. Institutional indicators are interacted with each other to create four institutional variables for analysis: public without a medical school, private without a medical school, public with a medical school, and private with a medical school; in addition to research size and faculty quality, measured as number of citations received by a department's faculty in 1993 (Bulut & Moschini, 2009). This study finds private universities with a medical school have the highest levels of net revenues from technology licensing activities, significantly higher than a public institution without a medical school. The size of the institutions' research base also has a positive influence on net licensing revenues, significant for all universities except those in the lowest quantile.

The faculty quality measure (# of citations) is not significantly related to net licensing revenues. This latter study suggests private universities with a medical school and large research base are strong positive predictors of successful revenue generation from university licensing.

Summary

Findings vary for university and TLO characteristics, with some finding no differences between public & private universities in licensing activity, while some find private universities more successful than public at obtaining licensing revenues. Bulut and Moschini's (2009) study interacts private and medical school indicators, finding schools with both of these characteristics are more successful obtaining licensing revenues than public universities without a medical school. Research funding, both federal and industry positively influence licensing and licensing revenues (Thursby & Thursby, 2007; Bulut & Moschini, 2009; Chukumba & Jensen, 2005). Quality of faculty, measured by the NRC rankings of graduate programs, has a positive influence on licensing and licensing revenues (Chukumba & Jensen, 2005; Powers & McDougall, 2005b; Markman, et al. 2009), while use of citations as a quality proxy for faculty is not significant (Bulut & Moschini, 2009). Controls for TLO size and prior licensing success are evaluated in several studies. Chukumba & Jensen (2005) find no influence of TLO size on licensing or revenues, potentially due to their use of gross royalties received as a measure of past success, which may have some correlation with TLO resources. Markman, et al., (2005a), Markman et al. (2009) and Thursby & Thursby (2007) all find a positive relationship between TLO size and licensing revenues received by the university.

The organizational structure of the TLO and licensing strategies used by the TLO can have an influence upon licensing revenues received from the technology transfer process; TLOs focused upon primary licensing strategies for industry sponsored research or upfront cash may generate less licensing revenues than TLOs with more flexibility and creativity in licensing. TLOs with low autonomy and centralized decision authority may have less flexibility in negotiating terms that could improve licensing revenues (Markman, et al., 2009). Incentive structures and university policy

orientation can influence university licensing efforts and licensing royalties. Findings from various studies on royalty sharing with inventors and their departments are mixed. Friedman and Silberman (2003) find higher royalty sharing with inventors has a positive relationship with licenses completed and royalty revenues received in 1999, but higher royalty sharing rates with the inventor's departments are a negative influence upon licenses executed, suggesting higher revenue sharing with inventors may have a positive influence on individual entrepreneurship, but university departments may not view entrepreneurial activities as important to departmental goals. Markman, et al., (2009) have opposite findings on royalty sharing incentives; their study finds a higher royalty sharing percentage with inventors has a negative relationship with licensing revenues, while higher sharing percentages with an inventor's department has a positive relationship with licensing revenues received between 1999-2002. Findings from Markman, et al.'s (2009) study suggests some universities may have implemented high royalty sharing policies with inventors and departmental support to incentivize disclosure and entrepreneurial activities, but may be lagging behind peer institutions. Friedman and Silberman's (2003) findings for 75 universities are limited to a single year of outcome data (1999), while Markman, et al.'s (2009) study has a larger sample (128 universities), and uses averaged licensing revenues received over four years, reducing any potential anomalies in data that might bias results. Increasing quality of academic faculty through hiring practices, expanding federal research activities, encouraging industry funded research, and enhancing the commercialization expertise of the TLO through hiring experienced licensing professionals may have a positive impact on general licensing practices of the university. Findings from these studies are summarized in table 2.3 below.

Table 2.3 Characteristics Influencing Licensing and Licensing Revenues

University Characteristics			
Characteristic	Study	TT Outcome	Findings
Private & Land grant	Friedman & Silberman, (2003)	Licenses, licensing revenue in 1999	No significant influence on licensing or licensing revenues
Private	Chukumba & Jensen, (2005)	# of licenses (1993-2002)	No significance on licensing activity
Public	Markman, et al., (2005a)	Logged revenues (2000 & 2002)	Public universities generate less revenue than private
	Markman, et al., (2009)	Average annual licensing revenues (1999-2002)	Public universities generate less revenues than private
Private/Medical	Bulut & Moschini, (2009)	Net revenues	Private universities with a medical school obtain significantly higher returns than public universities without a medical school
Medical	Chukumba & Jensen, (2005)	# of licenses (1993-2002)	Presence of medical school has no significant influence on licensing
	Friedman & Silberman, (2003)	Licenses, licensing revenue in 1999	No significant influence on licensing or licensing revenues
University size	Thursby & Kemp, (2002)	Licenses	Smallest and largest universities are more efficient in licensing efforts than mid-size universities
Federal research funding	Thursby & Thursby (2007)	Licensing revenue	Higher research levels has a positive influence upon licensing income
	Bulut & Moschini, (2009)	Net revenues	Research funding (univ. size) has strong influence on licensing revenues, significant for all universities except those in smallest (0.10th) quintile
Industry funding	Chukumba & Jensen, (2005)	# of licenses (1993-2002)	% of industry funding has a positive influence on licensing
Entrepreneurial policy orientation	Powers & McDougall, (2005b)	Average revenues (99-00)	Universities focused upon licensing to startups combined with large TLOs may receive less revenues
Incentive policies	Friedman & Silberman, (2003)	Licenses, licensing revenue in 1999	Higher royalty sharing % with inventor's department has a negative influence upon licenses, royalty sharing % with inventor has a positive relationship with license revenues
	Markman, et al. (2009)	Average annual licensing revenues (1999-2002),	Inventor royalty % has negative correlation with licensing revenues, while department % has positive correlation with licensing revenues.

Table 2.3 (*continued*)

Faculty quality	Chukumba & Jensen, (2005)	# of licenses (1993-2002)	NRC faculty quality rankings positively related to licensing
	Powers & McDougall, (2005b)	Average revenues (99-00)	Faculty quality strong influence for royalty income
	Markman, et al. (2009)	Average annual licensing revenues (1999-2002)	Quality of faculty (1995 NRC survey of graduate faculty) significant for licensing revenues
	Bulut & Moschini, (2009)	Net revenues	Faculty quality (log of citations) not significantly correlated with net licensing revenues
Faculty involvement in TT process	Markman, et al., (2005a)	Logged revenues (2000 & 2002)	Faculty may increase time via inventor-related resistance, indifference, and poor-quality disclosures
TLO Characteristics			
Characteristic	Study	TT Outcome	Findings
Age of TLO	Chukumba & Jensen, (2005)	# of licenses (1993-2002)	Age of TLO strongly correlated with increased licensing activities
	Friedman & Silberman, (2003)	licenses, licensing revenue in 1999	Experienced TLOs more likely to have higher rates of licensing & licensing revenues.
	Powers & McDougall, (2005b)	Average revenues (99-00)	Age of TLO has positive influence on royalty revenues
	Markman, et al., (2005a)	Logged revenues (2000 & 2002)	TLO experience (age) not significantly related to revenue generation.
	Markman, et al., (2009)	Average annual licensing revenues (1999-2002)	Age of TLO not significant for revenues
Prior experience	Chukumba & Jensen, (2005)	# of licenses (1993-2002)	Royalty income from previous licenses positively correlated with licensing
	Thursby & Thursby, (2007)	Licensing revenue	Prior licensing success (# of licenses generating income) has a positive influence upon licensing revenues
Disclosures received by TLO	Friedman & Silberman, (2003)	Licenses, licensing revenue in 1999	Higher levels of invention disclosures are critical for licensing.
	Chukumba & Jensen, (2005)	# of licenses (1993-2002)	# Disclosures received is a strong positive influence on licensing activities
TLO Size	Chukumba & Jensen, (2005)	# of licenses (1993-2002)	TLO size not significant for licensing
	Markman, et al., (2005a)	Logged revenues (2000 & 2002)	Larger TLOs have positive influence on revenues, and reduce time to license
	Thursby & Thursby, (2007)	Licensing revenue	Larger TLOs generate more revenues
	Markman, et al. (2009)	Average annual licensing revenues (1999-2002)	Larger TLOs more successful with licensing revenues

Table 2.3 (*continued*)

Business skills	Markman, et al., (2005a)	Logged revenues (2000 & 2002)	Lack of business competencies (# of contacts to license) increases commercialization time, negative influence on licensing revenues
	Markman, et al., (2009)	Average annual licensing revenues (1999-2002)	Higher TLO staff salaries has no significant influence on revenues
TLO Structure	Markman, et al., (2005a)	Logged revenues (2000 & 2002)	Traditional structure has a negative relationship with revenues
	Markman, Gianiodis & Phan, (2009)	Average annual licensing revenues (1999-2002)	Low autonomy of the TLO has a negative correlation with revenues
Regional Characteristics			
Characteristic	Study	TT Outcome	Findings
Regional industry R&D	Friedman & Silberman, (2003)	licenses, licensing revenue in 1999	Technology industry R&D – higher concentration has a positive influence on licenses, use of equity and startups.
	Bulut & Moschini, (2009)	Net revenues	Regional R&D intensity facilitates revenues for universities already actively engaged in TT

Startups, IPO Events & Use of Equity

A variety of university and TLO characteristics are found to support university startup formation and the use of equity as a licensing mechanism. TLO experience (age), the university's policies and orientation towards startup formation and use of equity, the size and commercialization skills of the TLO, faculty quality, levels of industry sponsored research at the university, regional entrepreneurial density, industry R&D, and access to venture capital are all implicated as factors that influence the technology transfer process and support startup formation from the university. University and TLO history and prior success with startup activity and use of equity can have a strong positive influence on subsequent startup efforts (DiGregorio & Shane, 2003; O'Shea, et al., 2005; Jensen & Jones, 2011). Taking equity in startups or small companies in the form of stocks, options or warrants is one growing mechanism utilized by research universities in licensing inventions to startups (Brown & Soderstrom, 2007), in lieu of upfront cash payments for licensing fees or in exchange for delay of costs related to IP reimbursement. Unlike established firms, startups may lack

cash flow and the ability to pay upfront fees for intellectual property licenses. University support in taking equity from a licensing deal reduces cash outlay for the startup in the short run and facilitates investment in development of IP for commercialization (Feldman, et al, 2002). Equity allows the university to benefit when the startup successfully reaches an IPO or other liquidity event, providing something of value even if the initially licensed intellectual property is dropped (Bray & Lee, 2000; Feldman, et al., 2002). Findings from a range of studies on these characteristics provide insight on their overall influence on startup formation, the success of startups and small business becoming a publicly traded company and reaching an IPO event and university use of equity as a licensing mechanism.

Income received from licenses and university startups are determined by initial terms and conditions of licensing agreements. Short term licensing considerations include cash licensing, upfront licensing costs, reimbursement of IP costs, and defined royalty streams; while long term considerations can include equity ownership and proportions of asset sales. Accepting a combination of short and long term financial considerations from a licensee allows the university to realize the full potential of its initial investment in the innovations (Bray & Lee, 2000). A financial comparative analysis method used in a 2000 study, "University Revenues from Technology Transfer: Licensing Fees versus Equity Positions," compares financial outcomes from equity sales from university startups to revenue streams from average royalty bearing licenses, evaluating prevailing attitudes of 10 US research universities regarding the use of equity in licensing to startups (Bray & Lee, 2000). Average equity income from these 10 universities is compared to the average licensing income reported to the AUTM Annual Licensing Survey in 1996. The study finds some defining characteristics of universities utilizing equity in licensing. These universities are larger and more established, have larger TLOs, higher royalty income levels, and have a large number of invention disclosures to the TLO each year. The equity sales from these universities in occurred in states with high venture capital availability, suggesting a relationship may exist between these variables; the

regional availability of venture capital may act as a moderator to a small company's access to investment and its long term success (Bray & Lee, 2000). Typically, equity taken by a university in a licensee/startup is worth little until the company can gain investment and move the product or service towards the commercial market, combining equity with other licensing mechanisms can maximize the financial return available to research universities over the long term, and may even produce income faster than a license without equity (Bray & Lee, 2000). The universities comprising this study are larger research universities, not necessarily representative of all US research universities, but their findings indicate use of equity in licensing to startups in combinations with other mechanisms may have a positive influence on long run revenues for the university. The correlation between venture capital availability and large equity sales can benefit from further analysis to determine the influence this regional characteristic may have on the use of equity by universities. Feldman, et al., (2002) analyze equity use by 62 universities in 1998, modeled as a function of TLO age, cumulative licensing efforts, industry sponsored research, budgetary structure of the TLO, and relative experience in their study, "Equity and the Technology Transfer Strategies of American Research Universities." The existence of a medical school, private universities, and the Carnegie classification for research intensity provide institutional controls (Feldman, et al., 2002). This study finds prior history and experience in licensing, the presence of a medical school, and higher levels of industry funding have positive relationships with a TLO's use of equity. A non-linear relationship appears with cumulative licensing: equity use increases with TLO experience, but decreases with TLOs who have higher licensing levels (Feldman, et al., 2002). This divergence suggests a university with higher licensing activity may be focused on increasing revenues in the shorter term, and may be locked into direct licensing to industry rather than supporting startups. Self-funded TLO's are less likely to utilize equity in licensing in Feldman, et al.'s (2002) study, possibly due to a short-term focus on guaranteed revenues. Universities with research levels in the lower ranges ($15-40 million) and those institutions catching up to peers in technology transfer are also more likely to utilize equity in their licensing

deals in this study (Feldman, et al., 2002), suggesting smaller universities and relative newcomers to the field may be more willing to be creative in licensing to university startups. The changing perception on use of equity in licensing to startups is driven by increased TLO experience with this licensing mechanism, and the increased prestige and legitimacy of university startups across the US (Feldman, et al., 2002). This study is limited by its data collected at a single point in time on equity use by universities. Startup creation and subsequently the use of equity may vary each year; data from multiple years can help determine if the influence of these characteristics holds over time, but would require mechanisms to control for serial correlations and unobserved institutional effects. Endogenous or unobserved variables of the institution or region may also have an impact upon the university's use of equity.

Previous history and tradition of working with university startups has a strong positive influence on subsequent startup formation as well as use of equity in licensing. O'Shea, Allen, Chevalier and Roche (2005) studied 141 universities over a six year period (1995-2001) in their study "Entrepreneurial Orientation, Technology Transfer and Spinoff Performance of US Universities" to identify university characteristics and capabilities that can help explain variation in startup formation across universities. The annual number of startups is modeled in their study as a function of historical, human capital, financial and commercial characteristics, using a negative binomial model for count data with a high number of zeros that create skewness and over dispersion in the data. Random effects provided additional controls in their model for any unobserved heterogeneity in repeated measures over time. Previous experience working with startups, measured as the average number of startups formed from 14 years' previous history, has a significant positive relationship with startup activity for the six years included in this study (O'Shea, et al., 2005), suggesting universities who have successfully worked with startups in the past will continue to have higher rates of startup formation. High research levels in science, engineering, faculty quality measures, and the size of the TLO all positively influence a research university's ability to form startups, and a relatively high percentage of

industry research funding also facilitates startup formation (O'Shea, et al., 2005). Institutional controls, including indicators for public and land grant universities, the presence of a medical school, and the size of the university endowment do not have a significant influence upon startup formation in this study. Findings indicate regional knowledge infrastructure does not have a strong influence upon startup formation for the universities in their sample. Friedman & Silberman, (2003) include estimated invention disclosures in their models for startups and use of equity by 93 research universities from 1997 to 1999. University characteristics in their model include: private versus public institutions, the presence of a medical school, whether the institution is land grant, the age of the TLO, and incentive policies for inventors and their departments. The age of the TLO, and the regional measure of technology industry concentration are positively correlated with startup formation (Friedman & Silberman, 2003), suggesting experience of the TLO and ability to engage with regional business networks may have a positive influence on startup activity. The number of invention disclosures, as well as the experience levels (age) of the TLO, and the regional measure of technology industry concentration are strongly correlated with a university's use of equity (Friedman & Silberman, 2003), suggesting the TLOs experience and ability to engage with faculty to drive increased disclosure activity and network with regional partners may have a positive influence on equity use in licensing to university startups. The study controls for non-linearity of the data in the recursive model by logging all variables. There is a relatively high correlation among faculty quality, federal research, and industry research variables, suggesting there may be multicollinearity and endogeneity issues making causal determinations difficult (Friedman & Silberman, 2003). Using a ratio of industry to federal funding might help to address some multicollinearity in the model with both funding variables.

Policies on formal incentives to academic researchers and their departments in royalty sharing distributions and salary levels of TLO staff have an influence on startup formation and use of equity, and may incentivize entrepreneurial efforts of faculty and create an entrepreneurial culture

that embraces technology commercialization. DiGregorio and Shane (2003) evaluate university policies on taking equity in exchange for intellectual property and licensing costs in their study, "Why do some Universities Generate more Start-Ups than Others?," finding the proportion of industry funded university research, the university's intellectual eminence, and royalty sharing policies with inventors all factor into the formation of university startups and use of equity. Comparing cross-institutional variation in licensing policies across 116 universities from 1994-1998, this study finds willingness to use equity in licensing has a positive influence on startup formation. A low royalty sharing rate for faculty inventors is positively correlated with startup formation, possibly incentivizing entrepreneurial efforts of inventors for increased monetary gain (DiGregorio & Shane, 2003). Findings indicate a higher percentage of industry research funding is not significantly related to startup formation between 1994 and 1998. Regional venture capital availability and a university affiliated incubator also have little influence upon startup formation. The non-linearity of the count data with clustering around a few small numbers and a high number of zeros indicated use of a negative binomial regression model as the best fit, using generalized estimating equations (GEE) to control for autocorrelation from unobserved factors in repeated measures over time. A linear model with mechanisms to control for serial correlation between repeated measures may be an alternative, transforming count data via logs to normalize the dependent variables. Other forms of investment or regional support to university startups may be important in early stages of technology commercialization efforts, and their influence upon startup formation and use of equity by universities may benefit from further exploration. Smilor and Matthews' (2004) case study identifies three key factors influencing startup formation and use of equity: 1) strong cultural support from university leadership, 2) unequivocal support and resource commitment for the TLO function within the university, and 3) incentive systems designed to support entrepreneurial faculty. This benchmarking study finds universities generally willing to use equity in licensing but with certain caveats. This study also notes the dual focus of the university TLO; supporting the formation of

startups as well as marketing and negotiating licensing agreements with industry. These two very different activities requiring appropriate skill set alignment within the TLO, indicating the commercialization skills within the TLO may also have an influence on startup formation and use of equity. In their study, "Entrepreneurship from the Ivory Tower: Do Incentive Systems Matter?," Markman, Gianiodis, Phan & Balkin, (2004) evaluate academic incentive systems in the form of monetary payments to inventors, their department or institution, and salary levels of university technology licensing office personnel for their influence on use of equity and startup formation at 128 US research universities during 1999. This study finds incentive policies can "reinforce goal symmetry between technology commercialization and entrepreneurial activity" (Markman, Gianiodis, Phan, & Balkin, 2004, p. 354). Findings indicate monetary incentives for inventors are *negatively* related to the number startups and equity licenses, while salary compensation levels for TLO personnel (as a proxy measure of quality commercialization skills) are positively related to both the number of licenses using equity and startup formation (Markman, et al., 2004). The findings from this study suggest higher incentives to faculty for revenue sharing may have a negative influence upon startup formation by reducing the risk of staying within the academic environment (Markman, et al., 2004). Salaries of TLO personnel are used as a proxy for high quality and commercialization skills of the licensing staff, suggesting those TLOs with higher salary levels may be able to retain individuals who have commercialization skills and ability to work with entrepreneurial faculty and facilitate startups. Hierarchical regression methodology works well for measuring outcomes from activities nested in universities and technology regions. Logarithmic transformations for variables controlled for any potential issues of non-linearity, non-normality or heteroscedasticity. Findings suggest the presence of a medical school has a positive influence on startup formation, but not equity licensing. The level of research funding is a significant and positive predictor for both startups and use of equity. A negative relationship between the age of the TLO and both startup formation and use of equity suggests those who have more experience with direct licensing may be locked in to those

activities due to path dependency and focus upon short-term monetary gains (Markman, et al., 2004). This finding could also reflective of a single year's data for the 128 institutions, as university outcomes and relative productivity can fluctuate yearly; a finding noted by Kim's (2013) review of productivity changes in university technology transfer outcomes. A larger panel study or additional year's data averaged over time may be beneficial to see if the relationships between these incentive payment structures for faculty, their departments, and TLO personnel on startups and use of equity continue to hold.

Regional characteristics such as the availability of regional venture capital, local industry research and development, and entrepreneurial activities can also have an influence upon university technology commercialization efforts. Several studies suggest these regional characteristics may interact with institutional characteristics including faculty size and quality, TLO age, and industry research funding levels to influence academic startup formation. Powers and McDougall (2005a), evaluate startup formation and IPO events from university licensees for 120 research intensive and extensive institutions in their study, "University Start-Up Formation and Technology Licensing with Firms that go Public: A Resource Based View of Academic Entrepreneurship," evaluating university and regional characteristics and their influence upon entrepreneurial activities. This study totals data over 5 years, from 1996 to 2000, using a negative binomial model for count data. Findings indicate larger universities in terms of higher faculty levels are able to facilitate more startups, but aren't necessarily related to IPO events. Faculty quality is recognized as a strong positive predictor of both startups and IPO events. The age of the TLO, the level of industry research funding at the university, and the level of regional venture capital availability also all have a positive influence upon both startup formation and successful IPO events (Powers & McDougall 2005a). Endowment size of the university (a measure of wealth of the institution) is positively related to IPO events from university licensees in this study, but not startups; and the study finds the importance of the patent portfolio of the university to have little influence on startups or IPO events. Chukumba and Jensen (2005), in their

study “University Invention, Entrepreneurship and Start-ups,” also evaluate regional financial market characteristics in addition to institutional characteristics such as private institutions, the presence of a medical school, faculty quality, age of the TLO, invention disclosure receipt, and industry funding levels for their influence on startup formation. Specific attributes of 110 universities are evaluated using a negative binomial regression for over dispersed count data. Inventor quality, experienced TLOs, prior invention disclosures and gross royalties are all positively correlated with startup formation (Chukumba & Jensen 2005), suggesting prior experience and success in technology transfer activities in general have a positive influence on a university’s entrepreneurial activities. The size of the TLO is not significant for startup formation. Findings for regional financial market characteristics indicate venture capital funding in each state has a moderately positive influence on startup formation. The five year average return on investment (ROI) has a negative relationship with university startup formation, suggesting when returns to investment are high, venture capital investors may turn to more lucrative activities (Chukumba & Jensen, 2005). The ratio of industry to federal research funding is strongly correlated with startups, suggesting industry sponsored research has a positive influence on startup formation, while no difference is indicated for private institutions and medical schools. The findings from these studies suggest attributes under the control of the institution such as supporting industry sponsored research, hiring and supporting quality faculty, and enhancing the commercialization expertise of the TLO through training or hiring experienced licensing professionals who can leverage regional investment sources and other business resources may have a positive influence on startup formation.

University policies oriented toward startup formation and support of faculty entrepreneurial efforts may interact with regional characteristics to influence university startups. Powers and McDougall (2005b) compare differing institutional policies and attributes from 134 universities for their influence on successful IPO events of university licensees from 1996-2000, and how university entrepreneurial policies may interact with regional entrepreneurial characteristics. A hierarchical

moderated regression provides a mechanism to evaluate potential interactions between selectivity policies of the university, university support for the TLO, and regional entrepreneurial density; variables are averaged or logged to address normality issues and yearly fluctuations. This study finds universities oriented towards startups have higher levels of university startups or small businesses reaching successful IPO events than universities with less selective policies (Powers & McDougall 2005b). The level of statewide R&D activity, number of patents per state, the venture capital investment levels per state, and the number of SBIR & STTR grants provide measures for entrepreneurial density, each expressed as a proportion of the square mileage of each state. Regional entrepreneurial density has a positive relationship with IPO events for university licensees; however interactions between university selectivity policies and entrepreneurial density do not have a significant influence. University policies with strong orientation towards startups and larger TLOs in a strong regional entrepreneurial environment may be an overinvestment of scarce university resources, while university policies with low orientation towards startups, and smaller TLO support in weak entrepreneurial regions may represent an underinvestment for institutions trying to establish themselves as entrepreneurial universities (Powers & McDougall, 2005b). Control variables include the age of the TLO as a proxy for experience levels of the TLO, faculty quality, and a medical school. Faculty quality is strongly significant, and the age of the TLO moderately significant for IPO events. The proxy variables for TLO support and selectivity policies are rough measures for university entrepreneurial support, and may benefit from alternative measures (perhaps total TLO operating budget and total IP budget) for institutional TLO support measures.

Structural characteristics and licensing strategies of the TLO are additional characteristics identified as influencing university startup formation and use of equity. Markman, Phan, Balkin, & Gianiodis (2005b) in their study: "Entrepreneurship and University-Based Technology Transfer," use grounded theory to analyze qualitative data collected from long interviews with 128 university TLO directors to analyze the influence of TLO structure and licensing strategies on startups and use of

equity, and how they may be related. TLO structure is categorized in three groups: 1) the traditional structure is considered an integral part of the university, typically organized under and funded by the office of research, 2) a non-profit structure is separate from the university organized as a 501(C)3 research foundation, and 3) a for-profit structure can be either part of the university or part of a separate entity, but has a private venture extension focused upon creating startups from the university (Markman, et al., 2005b). Licensing strategies include licensing for sponsored research, cash, and equity. These characteristics are correlated with each other to evaluate how they might influence each other and the formation of university startups. Previous startups (1998-2001) and the presence of a university incubator are included in the correlation matrix. Findings suggest the traditional TLO structure has no significant correlation with startup activity, but may be likely to license university inventions for sponsored research or an equity portion. The non-profit structure indicates no correlation with either startup activity or use of equity, and is less likely to license for sponsored research, with no significant correlation with either cash or equity licensing. Findings for the for-profit structure indicate this TLO structure is strongly positively correlated with both startups and use of equity in licensing, but a negative correlation with cash licensing suggesting this structure may be strategically focused on startup formation (Markman, et al., 2005b). TLO licensing strategies also have an influence upon startup formation; sponsored research has a strong negative correlation with prior startup activity, and cash licensing has a negative correlation with current startup activity. Licensing for equity has strong positive correlations with both current and past startup activity. These findings indicate the structure of the TLO and its licensing strategies can strongly influence technology transfer outcomes, and university TLOs may benefit from using a variety of licensing strategies to meet needs of the inventor and the startup or licensee. Furthering this initial analysis, Markman, Bianiodis, and Phan (2009) evaluate the impact of TLO licensing strategies, TLO structure, including incentive payment policies with inventors and their departments, and TLO licensing personnel salaries, on startup formation from these 128 universities, using a 2 stage

hierarchical regression to model startup formation from 1998-2001, controlling for institutional characteristics, the age and size of the TLO, faculty quality measures and the presence of a university affiliated incubator. This study finds both TLO age and TLO size are positively related to startup formation, as well as faculty quality and the presence of an incubator; no significant difference is indicated for public institutions. Second stage regression includes characteristics of TLO licensing strategies (licensing for sponsored research versus licensing for cash), TLO structure (the three structures used previously collapsed into two contrast codes for low versus high autonomy), and university incentive policies in the form of percentage sharing of revenues with inventors and their departments, and TLO salaries (Markman, et al., 2009). Licensing strategies (for sponsored research and cash) show no significant influence upon startup formation. High TLO structural autonomy is found to have a positive influence upon startup formation. Findings for incentive royalty sharing policies for inventors indicate a negative relationship between percentage sharing with inventors and startup formation, with no significance for payments to inventor departments. TLO salary levels are significantly related to startup formation, suggesting high salaried licensing professionals may have a combination of competencies (technical aptitude, knowledge of IP law, negotiating, business planning capabilities and networks, and industry knowledge) that support successful startup formation (Markman, et al., 2009). A shorter time to commercialization can support successful startup efforts from academic technology transfer activities. Markman, Gianiodis, Phan and Balkin (2005a), in their study, "Innovation Speed: Transferring University Technologies to Market," find longer commercialization time is negatively related to new venture creation. Other characteristics evaluated in this study include TLO age and size, whether the university is a public institution, and the structure of the TLO. Findings for TLO structure (traditional, non-profit and for-profit), suggest the traditional TLO structure has a positive relationship with startup formation, but may take longer to form the startup when compared to the non-profit structure. For-profit TLO structure is not significantly related to startup formation, but is strongly correlated with a shorter time to startup formation than the

non-profit structure (Markman, et al., 2005a). TLO age and size are both positively related to startup formation, and TLO experience can shorten time to startup formation. A lack of commercialization competencies of the TLO can significantly increase time to startup formation. The findings from this analysis suggest time to commercialization for startups is shorter for larger, more experienced TLOs under a for-profit organizational structure. These studies on TLO structural characteristics and licensing strategies support previous findings on university characteristic and incentive structures, and provide additional evaluation of TLO organizational structural influence on entrepreneurial efforts of the university.

Entrepreneurial activities of academic faculty may be more likely to happen during difficult economic times when potential risks are reduced relative to direct licensing activities. A 2011 study "University Startups and Entrepreneurship: New Data, New Results," by Jensen and Jones (2011) analyzes how university, TLO, and regional characteristics affect university entrepreneurial activities before and after the NASDAQ stock market crash in 2000. Data is evaluated on startup activity for all universities that reported to AUTM from 1994 to 2008, modeled as a function of university, departmental and economic characteristics. A negative binomial method is applied to the count of startups each year. A random effects method allows the exploitation of an unbalanced panel from several years of observations for the units of observations. This study evaluates several institutional and TLO characteristics, including indicators for private and land-grant institutions, federal and industry research funding levels, TLO age and size, a measure of historical disclosures to the TLO, quality measures for faculty, and prior startup formation efforts. Disclosures received by the TLO have a positive relationship with startup activity, confirming the importance of this critical input as "the lifeblood of startups" (Jensen & Jones, 2011, p. 13). The size of engineering and physical science faculty and the quality of biological faculty have a positive influence upon startup formation. Research funding level has a positive influence on startup formation, with significance of federal funding levels increasing after 2001; industry research funding also has strong impact. TLO age and

size also have a strong positive influence, and if a TLO has had experience working with a startup in the past they are more likely to work with startups in the future. Faculty quality, particularly of engineering and biological sciences, has increased in importance after 2000 for startup formation. Findings indicate that after the dot-com collapse in 2000, characteristics of universities and TLOs influencing startup activity have changed, suggesting a need for continued evaluation of how university startups are formed in changing economic environments.

Summary

Institutional characteristics are commonly used to control for type and size of an institution in these research studies, but findings from several studies indicate various institutional factors can have an influence on startup formation from US research universities. Private universities are not necessarily better at startup formation than public (Chukumba & Jensen, 2005; Markman, et al., 2009), but may be able to move more quickly to startup formation (Markman, et al., 2005a). A recent study by Jensen & Jones (2011), finds private & land-grant universities are less likely to form startups than public institutions. The presence of a medical school also has mixed results, some find the presence of a medical school can positively influence startup formation (Markman, et al., 2004), while others find this school has little influence upon startup formation (Chukumba & Jensen, 2005; Jensen & Jones, 2011). Feldman, et al., (2002) find the presence of a medical school has a positive relationship with the use of equity in licensing, while Markman, et al., (2004) find no significance for the presence of a medical school on use of equity. Endowment of the university, as an indicator of a university's wealth can have a positive influence on startup formation (Powers & McDougall, 2005a).

Disclosures are driven by research funding (Friedman & Silberman, 2003), and the number of disclosures received by the TLO have a significant relationship with university startup formation and use of equity. Studies find TLOs with a high number of disclosures are more likely to use equity, (Bray & Lee, 2000; Friedman & Silberman, 2003). A large number of disclosures in the technology transfer pipeline are critical for startup formation; findings from two studies note the number of

disclosures received by the TLO is a significant predictor for university startup formation (Chukumba & Jensen, 2005; Jensen & Jones, 2011).

Federal and industry research funding levels of universities can have a significant influence upon startup formation and use of equity in licensing, however findings differ among studies. Larger research universities are more likely to form startups and utilize equity with startups, (Bray & Lee, 2000; Markman et. al., 2004; Jensen & Jones, 2011), particularly with high levels of research funding in science and engineering (O'Shea, et al., 2005). Feldman, et al., (2002) find universities federal funding levels in the $15-40 million range and higher levels of industry funded research are more likely to use equity. Universities considered lagging in technology transfer also use equity more than those universities already actively engaged in technology transfer efforts (Feldman, et al., 2002), which may help to explain why smaller research institutions may be more likely to use equity than larger. Several studies find the levels of industry funding at a university can have a strong positive influence upon a university's ability to form startup companies (O'Shea, et al., 2005; Chukumba & Jensen, 2005; Jensen & Jones, 2011), and their success in reaching an IPO event (Powers & McDougall, 2005a). DiGregorio & Shane (2003) find a higher percentage of industry research funding does not have a significant influence on startups, potentially due to a lagged effect.

The entrepreneurial policy orientation of the university has an influence on startup formation, with several finding a *low* royalty sharing rate with university inventors has a positive influence on startups and use of equity (DiGregorio & Shane, 2003; Markman, et al., 2004; Markman, et al., 2009), potentially stimulating entrepreneurial activity of faculty for increased monetary gains. Strong support from university leadership can have a positive influence on startup formation (O'Shea, et al., 2005), and university policies oriented towards startup formation are a positive influence on both startup formation and successful IPO events for university licensees. These university policies may be adjusted to reflect the university's entrepreneurial environment (Powers & McDougall, 2005b).

Faculty quality is a strong influence upon startups, IPO events, and use of equity (DiGregorio & Shane, 2003; O'Shea, et al., 2005; Powers & McDougall, 2005a; Chukumba & Jensen, 2005; Powers & McDougall, 2005b; Markman et al., 2009; Jensen & Jones, 2011). Faculty size is moderately related to startup formation, (Powers & McDougall, 2005a), the numbers of bioscience faculty more so since 2002 (Jensen & Jones, 2011). Faculty engagement in the technology transfer process is critical to startup formation and can speed up the process, while the number of inventors from different universities can increase the amount of time before a startup forms (Markman, et al., 2005a).

The age of the TLO is positively correlated with startup activity, IPO events, and use of equity in licensing, suggesting older TLOs may be more experienced and willing to work with entrepreneurial faculty, or that faculty may be better informed of entrepreneurial options by the TLO (Friedman & Silberman, 2003; Powers & McDougall, 2005a; Chukumba & Jensen, 2005; Powers & McDougall, 2005b; Markman, et al., 2005a; Markman et al., 2009; Jensen & Jones, 2011). Studies find different relationships exist between the age of the TLO and equity use, experienced TLOs utilize equity more than others (Friedman & Silberman, 2003), but less so with cumulative licensing efforts (Feldman, et al., 2002); while another study finds a negative relationship between equity use and age of the TLO (Markman, et al., 2004), suggesting TLOs with more experience in direct licensing may be locked in to that activity due to path dependency & focus on short-term gains. Previous success and experience of the TLO in licensing activities, startup formation and use of equity matter, positively influencing subsequent activities (Feldman, et al., 2002; DiGregorio & Shane, 2003; O'Shea, et al., 2005;Chukumba & Jensen 2005; Markman, et al., 2005b; Jensen & Jones, 2011).

A lack of commercialization capabilities of the TLO is implicated as a possible impediment to startup formation (Markman, et al., 2005a), suggesting increased commercialization training or hiring skilled licensing professionals in the TLO may minimize time in finding business contacts for

licensing or startup formation. Smilor and Mathews (2004), in their qualitative analysis also find the duality of the TLO function (licensing and startup activity) require appropriate skills to facilitate both types of commercialization paths, different for licensing directly to industry than working with startups. Higher compensation levels of TLO licensing staff is also positively correlated with use of equity and startup formation, compensation packages used as a proxy for advanced commercialization skills (Markman, et al., 2004; Markman, et al., 2009). These findings suggest highly skilled licensing professionals able to command higher salaries may support university startup efforts more effectively than those less able to command higher salary levels.

Various structures of the TLO can also influence university startup formation. Feldman, et al., (2002) find self-sustaining TLOs are less likely to use equity as a licensing mechanism due to a short-term focus on revenue generation needed for operations. Three organizational structures of the TLO are analyzed by Markman, et al., (2005a, 2005b) for their influence on startup formation and use of equity: 1) a traditional structure of the TLO as an integral part of the university, 2) a non-profit structure, separate from the university, commonly organized as a 501(C)3 research foundation, and 3) a for-profit structure that has a private venture extension focused upon creating startups from the university (Markman, et al., 2005a; Markman, et al., 2005b). Findings from these studies indicate the traditional structure of the TLO takes longer to startup formation, but may be willing to utilize equity in licensing; and a for-profit TLO structure is significantly and positively related to both startup formation and use of equity, is able to form startups more quickly when compared to the non-profit TLO structure. Markman, et al. (2009), find high TLO autonomy has a positive influence on startup formation, due to increased flexibility in licensing and ability to leverage external resources in support of entrepreneurial efforts. Licensing strategies of the TLO focused upon obtaining sponsored research funding or cash payments from licensees have a negative correlation with startup formation, while licensing for equity can have a positive influence on the formation of startups from a research university (Markman, et al., 2005b).

Regional characteristics can also influence startup formation from universities. A high concentration of industry research and development in the region has a positive relationship with startup formation (Friedman & Silberman, 2003), as does financial resource availability, access to venture capital, and entrepreneurial density (Bray & Lee, 2000; DiGregorio & Shane, 2003; Powers & McDougall, 2005a; Chukumba & Jensen, 2005; Powers & McDougall, 2005b). The presence of a university affiliated incubator is positively related to startup formation (DiGregorio & Shane, 2003, O'Shea, et al., 2005; Markman, et al., 2009). These findings are summarized in table 2.4 below.

Table 2.4 Characteristics Influencing Startup Formation, IPO Events & Equity Use

University Characteristics			
Characteristic	Study	TT Outcome	Findings
Private	Chukumba & Jensen, (2005)	# of startups (1993-2002)	No significance on startup activity
Public	Markman, et al., (2005a)	# of startups (2000 & 2002)	Public universities time to startups formation longer than private
	Markman et al., (2009)	Average # of spinouts (1998–2001)	Public universities not significant for startup formation
Private/land grant	Jensen & Jones (2011)	# Startups 1994-2008	Private & land grant universities are less likely to form startups
Medical	Feldman, et al., (2002)	% of equity investment: through 1998	Presence of a medical school positively correlated with use of equity in licensing
	Markman et al., (2004)	(1999) # equity licenses, & # startups	Presence of a medical school has positive influence upon startup formation, but not equity licensing
	Chukumba & Jensen, (2005)	# of startups (1993-2002)	Presence of medical school has no significant influence on startup formation
	Jensen & Jones, (2011)	Startups 1994-2008	No significance for presence of medical school
Endowment	Powers & McDougall, (2005a)	# startups & # of IPO events (1996-2000)	Endowment of universities levels have positive influence on IPO events

Table 2.4 (*continued*)

Federal research funding	Bray & Lee, (2000)	Use and value of equity (equity sale compared to return on average license)	Larger research universities & established institutions more likely to utilize equity with startups
	Feldman, et al., (2002)	% of equity investment: through 1998	High Research Universities >$40 million are less likely to use equity than those with research levels in the $15-40 million range
	Markman et. al., (2004)	(1999) # equity licenses, & # startups	Research funding levels are a strong positive influence upon use of equity in licensing and startup formation
	O'Shea, et al., (2005)	# of startups per year	Strong research funding base in science and engineering facilitates startup activity
	Jensen & Jones, (2011)	# Startups 1994-2008	Federal funding levels are an important influence on startup activity
Industry funding	Feldman, et al., (2002)	% of equity investment: through 1998	Higher levels of industry funded research has positive influence on the use of equity
	DiGregorio & Shane, (2003)	# of startups (1994-1998)	Higher % of industry research funding is not significant – potentially due to a lagged effect
	O'Shea, et al., (2005)	# of startups per year	High percentage of industry funding has positive influence on startups
	Powers & McDougall, (2005a)	# startups & # of IPO events (1996-2000)	Previous levels of industry research funding positive influence on startup formation and IPO events 1996-2000
	Chukumba & Jensen, (2005)	# of startups (1993-2002)	Positive influence on startup formation with controls for faculty quality
	Jensen & Jones, (2011)	# Startups 1994-2008	Strong influence upon startups stronger than federal funding
Entrepreneurial policy orientation	DiGregorio & Shane, (2003)	# of startups (1994-1998)	Ability to use equity in licensing and low royalty sharing % with inventors has a positive influence on startups
	Powers & McDougall, (2005b)	Average IPO events (96-00)	Support structures and policies in support of startups may be adjusted to reflect entrepreneurial environment
TLO support	O'Shea, et al., (2005)	# of startups per year	Strong support for the TLO facilitates startups
Lagging cohort	Feldman, et al., (2002)	% of equity investment: through 1998	Lagging cohort in TT more likely to use equity
Incentive policies	Markman, et al., (2004)	(1999) # equity licenses, & # startups	Higher royalty % with inventors has a negative influence upon both use of equity and startup formation, payment to faculty departments not significant.
	Markman, et al., (2009)	Average # of spinouts (1998–2001)	Inventor royalty sharing % has negative influence on startups
	DiGregorio & Shane, (2003)	# of startups (1994-1998)	Higher rates of inventor royalty sharing negatively influences startups

Table 2.4 (*continued*)

Faculty quality	DiGregorio & Shane, (2003)	# of startups (1994-1998)	Intellectual eminence (graduate school score)correlated with startup formation
	O'Shea, et al., (2005)	# of startups/year	important for startup formation
	Powers & McDougall, (2005a)	# startups & # of IPO events (1996-2000)	Strong positive predictor of startup and IPO events
	Chukumba & Jensen, (2005)	# of startups (1993-2002)	Positively related to startups, engineering more so than science
	Powers & McDougall, (2005b)	Average IPO events (96-00)	Faculty quality strong influence for successful IPO events
	Markman, et al., (2009)	Average # of spinouts (1998–2001)	Quality of faculty (1995 NRC survey of graduate faculty) significant for startup formation
	Jensen & Jones, (2011)	# Startups 1994-2008	Engin faculty quality important after 2000 for startups
Faculty size	Powers & McDougall, (2005a)	# startups & # of IPO events (1996-2000)	Size of faculty has moderate positive influence on startup formation
	Jensen & Jones, (2011)	# Startups 1994-2008	Bioscience faculty size important after 2000 for startups
Faculty involvement in TT process	Markman, et al., (2005a)	Logged # of startups (2000 & 2002)	Faculty engagement critical for startup formation, impediments to commercialization posed by inventor-related resistance, indifference, and poor-quality disclosures
TLO Characteristics			
Characteristic	Study	TT Outcome	Findings
Disclosures received by TLO	Bray & Lee, (2000)	Use and value of equity (equity sale compared to return on average license)	TLOs with a high number of disclosures are more likely to use equity
	Friedman & Silberman, (2003)	startups, licenses with equity 1999	Higher levels of invention disclosures influences use of equity in licensing.
	Chukumba & Jensen, (2005)	# of startups (1993-2002)	# Disclosures is a strong positive influence and startup formation
	Jensen & Jones, (2011)	# Startups 1994-2008	Lagged disclosures – large # of disclosures in the pipeline are critical for startup formation (# disclosures strong significant predictor)

Table 2.4 (*continued*)

Size of TLO	Bray & Lee, (2000)	Use and value of equity	Universities with larger TLOs use equity more than others
	DiGregorio & Shane, (2003)	# of startups (1994-1998)	Size of TLO not significant for startup activity
	Markman, et al., (2005a)	Logged # of startups (2000 & 2002)	Larger TLOs have positive influence on startup formation, but no significant reduction in time to startup
	Chukumba & Jensen, (2005)	# of startups (1993-2002)	TLO size not significant for startup formation
	O'Shea, et al., (2005)	# of startups per year	Size of TLO positive influence on startup formation
	Markman, et al., (2009)	Average # of spinouts (1998–2001)	Larger TLOs more successful with startups (1%)
	Jensen & Jones, (2011)	# Startups 1994-2008	Larger TLOs more successful with startups
Age of TLO	Feldman, Feller, Bercovitz and Burton, (2002)	% of equity investment: through 1998	Age is a positive influence on use of equity
	Friedman & Silberman, (2003)	2nd stage DVs= startups, licenses with equity 1999	Experienced TLOs more likely to have higher rates of startup formation and use of equity.
	Markman, et al., (2004)	(1999) # equity licenses, & # startups.	Age of TLO negatively related to startups and use of equity (unexpected)
	Powers & McDougall, (2005a)	# startups & # of IPO events (1996-2000)	Age of TLO strong positive predictor of startup and IPO events
	Chukumba & Jensen, (2005)	# of startups (1993-2002)	Age of TLO moderately correlated with startup formation – suggests those universities able to form startups may not be same as those with high royalty income from licensing (p 18)
	Powers & McDougall, (2005b)	Average IPO events (96-00)	Age of TLO has positive influence on IPO events and royalty income
	Markman, et al., (2005a)	Logged # of startups (2000 & 2002)	TLO experience (age) has a positive influence upon new venture formation; significantly reduces commercialization time to startup
	Markman, et al., (2009)	Average # of spinouts (1998–2001)	Age of TLO has a strong positive correlation with startup formation
	Jensen & Jones, (2011)	# Startups 1994-2008	Age of TLO has strong positive influence upon startup formation

Table 2.4 (*continued*)

Prior experience & success	Feldman, Feller, Bercovitz and Burton, (2002)	% of equity investment: through 1998	Experience with licensing increases equity use, decreases with higher levels of licensing activities
	DiGregorio & Shane, (2003)	# of startups (1994-1998)	Previous experience with equity significantly influences subsequent startup formation
	O'Shea, et al., (2005)	# of startups per year	Previous success in startup formation stimulates subsequent startups.
	Chukumba & Jensen, (2005)	# of startups (1993-2002)	Revenue from previous successful licenses somewhat positively correlated with 1993-2002 startups
	Markman et al., (2005b)	Startups in 2002	Prior experience with startups has strong positive influence upon subsequent startup formation
	Jensen & Jones, (2011)	# Startups 1994-2008	Hurdle – prior experience with startup increases probability of subsequent startup rate by 1.56
Business skills	Smilor & Matthews, (2004)	TLO (budget, staff, $, #licenses, #startups, equity use) Royalty distribution	Dual focus of the TLO requires alignment with appropriate skill sets to increase startup activity Links to business resources are key.
	Markman, et al., (2004) (proxy – Salaries)	(1999) # equity licenses, & # startups.	TLOs with higher salaries have a strong positive influence upon use of equity and startup formation
	Markman, et al., (2005a)	# of startups (2000 & 2002)	Lack of business competencies in TLO increases time to commercialization, a negative influence on startup formation
	Markman, et al., (2009) (proxy – Salaries)	Average # of spinouts (1998–2001)	Higher TLO staff salaries have a strong positive influence upon startup formation (1%)
TLO Structure	Feldman, Feller, Bercovitz and Burton, (2002)	% of equity investment: through 1998	Self-Sustaining TLO is less likely to use equity due to shorter term focus on operating expenses.
	Markman, et al., (2005a)	# of startups (2000 & 2002)	Traditional structure, has a negative influence on startup formation, & increases time to startup; For-profit structure has lowered time to startup
	Markman, et al., (2005b)	Startups in 2002	Traditional structure positively correlated with use of equity Non-profit – no significance for startup or equity use For profit – significantly correlated with both startup and equity use
	Markman, et al., (2009)	Average # of spinouts (1998–2001)	High autonomy – positive influence on startup formation
Licensing Strategies of TLO	Markman, et al., (2005b)	Startups in 2002	Sponsored Research – Strong negative correlation with startup formation Cash – negative correlation w/ startup Equity – strong positive influence upon startup formation

Table 2.4 (*continued*)

Regional Characteristics			
Characteristic	Study	TT Outcome	Findings
Regional Industry R&D	Friedman & Silberman, (2003)	startups, licenses with equity 1999	Higher concentration has a positive influence use of equity and startups.
Incubator	DiGregorio & Shane, (2003)	# of startups (1994-1998)	Incubator has little influence upon university startup formation
	O'Shea, et al., (2005)	# of startups per year	Incubator has positive influence upon startup formation
	Markman, et al., (2009)	Average # of spinouts (1998–2001)	Incubator has positive influence upon startup formation
VC availability	Bray & Lee, (2000)	value of equity sold from startup compared to return on average license	Highest returns from equity come from high dollar sales in regions with high VC availability
	DiGregorio & Shane, (2003)	# of startups (1994-1998)	VC availability in regional MSA has little effect on startup activity.
	Powers & McDougall, (2005a)	# startups & # of IPO events (1996-2000)	regional venture capital availability facilitates startup formation
	Chukumba & Jensen, (2005)	# of startups (1993-2002)	VC investment in state has positive influence on startup activity, but less so when interest rates are high or returns to VC funding is high
Entrepreneurial Density	Powers & McDougall, (2005b)	Average IPO events (96-00)	Regional entrepreneurial density has positive influence on IPO events from startups/small company licensees

Discussion

This literature review set out to discover what the body of research on university technology transfer can tell us about various characteristics and attributes that influence the technology transfer process itself, the characteristics related to invention disclosure submission from research faculty as a primary input into that process, and if there are different characteristics and attributes that have an influence upon licensing activities versus the formation of startups. The research studies in this literature review provide information regarding the multi stage process of technology transfer, and the various university, TLO, and regional characteristics that have an influence on that process and its outcomes. Institutional and organizational characteristics of universities and the TLO, as well as some regional characteristics influence institutional efficiency and effectiveness. Institutional characteristics such as institutional size (as determined by numbers of faculty), private universities,

the presence of medical school are not necessarily determinants of efficiency or growth in technology transfer activities, this growth is more likely influenced by a changing entrepreneurial culture, willingness of faculty to engage, and university support from leadership (Thursby & Thursby, 2002, Thursby & Kemp, 2002). The smallest and largest universities are more effective than mid-range universities in working with disclosures, licenses and licensing revenue (Thursby & Kemp, 2002), suggesting mid-range universities may wish to evaluate whether the resources allocated to support technology transfer are appropriate. Larger TLOs are relatively more efficient in licensing activity, older more so with revenues (Siegel, et al., 2003). Growth in the TLO may decrease relative efficiency levels due to steep learning curve of new licensing staff (Thursby & Kemp, 2002) in developing knowledge of the university, its research base, and making contacts with industry. Business and commercialization skills in the TLO are noted in two qualitative studies as important to TLO effectiveness, influencing invention disclosures, licensing efforts and startup formation (Siegel, et al., 2003; Smilor and Matthews, 2004).

Invention disclosures to the TLO are critical to and initiate the technology transfer process. Entrepreneurial culture, supportive leadership and increased participation by faculty all drive invention disclosure to the TLO (Thursby & Thursby, 2002). Research funding levels are somewhat related to higher efficiency levels, and the number of science departments with graduate programs at a university has a positive relationship with the number of disclosures received by a TLO (Friedman & Silberman, 2003). Incoming disclosures have a strong positive influence upon a university's relative efficiency, suggesting the rate of disclosures per research funding levels may be an interesting characteristic to for further evaluation. Faculty quality and high federal and industry research funding levels have a strong positive correlation with invention disclosures, critical inputs into the technology commercialization process (Friedman & Silberman, 2003; Siegel, et al., 2003; Jensen & Jones, 2011). Qualitative field work and case study analysis suggest relationships between the TLO and research

faculty may have a positive influence upon invention disclosure rates (Siegel, et al., 2003; Smilor & Matthews, 2004).

Licensing efforts and their resulting revenue streams are influenced by many characteristics and attributes of universities, TLOs and regions. While institutional characteristics are not necessarily related to efficiency, the combination of a private university with a medical school is indicated as being able to generate more revenues than a public university without a medical school (Bulut & Moschini, 2009). Federal funding levels have a strong positive correlation with higher licensing revenues (Thursby & Thursby, 2007; Bulut & Moschini, 2009), and industry funding levels also have a positive influence on licensing activity, (Chukumba & Jensen, 2005). Research funding is positively correlated with disclosure activity, and the quantity of disclosures in the technology commercialization pipeline have a positive influence upon licensing activities (Friedman & Silberman, 2003, Chukumba & Jensen, 2005), suggesting larger universities with higher levels of research activities in general may have more effectiveness in technology transfer overall due to the amount of research funds directed their way. Findings for incentive structures and royalty rate sharing policies are ambiguous for their influence on licensing activities; Friedman & Silberrnan (2003) find higher royalty sharing positively related to revenues during 1997-1999, while Markman, et al. (2009), find the opposite relationship for revenues in 2002, indicating faculty incentives for more recent entrepreneurial activities may be determined by factors outside of monetary incentives. Quality of faculty inventors, as measured by NRC rankings, has a strong correlation with licensing and licensing revenues (Chukumba & Jensen, 2005; Powers & McDougall, 2005b; Markman, et al., 2009), while faculty citations in technology departments, used by Bulut & Moschini (2009), do not seem to be significantly related to licensing revenues. Faculty involvement in commercialization efforts signals their entrepreneurial orientation, and can increase the speed to commercialization (Markman, et al., 2005a). Experience of the TLO (age) is positively related to licensing activity (Chukumba & Jensen, 2005; Friedman & Silberman, 2003), and findings are mixed for revenues; some finding a positive

correlation (Powers & McDougall, 2005b), others finding no significant relationship between TLO age and licensing revenues received by the university (Markman, et al., 2005a; Markman, et al., 2009). Larger TLOs are positively correlated with licensing activities, and can reduce commercialization time (Markman, et al., 2005a; Thursby & Thursby, 2007; Markman, et al., 2009). A prior history of success with licensing, measured via the revenue obtained from previous licensing (Chukumba & Jensen, 2005; Thursby & Thursby, 2007) has a strong positive correlation with both the number of licenses and current revenue streams, suggesting that historical success may have an influence on current activities rather than outright years of experience. Business and commercialization skills of the licensing staff within the TLO may increase speed to licensing (Markman, et al., 2005a), salary levels of the TLO, used as a proxy for higher skilled staff, are not significantly correlated with licensing efforts (Markman, et al., 2009). The structure of the TLO can also have an influence upon technology transfer outcomes. Markman, et al. (2005) find TLOs under a traditional structure within the university or those with low autonomy generate less licensing revenues (Markman, et al., 2005a; Markman, et al, 2009), suggesting TLOs separate from the university and able to work autonomously may be more effective in licensing university inventions. Regional industry research and development levels can also have a positive influence on licensing efforts and revenue generation (Friedman & Silberman, 2003; Bulut & Moschini, 2009).

Startup formation and the use of equity as a mechanism for academic licensing with startups has become more normalized (Jensen & Jones, 2011; Feldman, et al., 2002; Markman, et al., 2004), with more universities reporting the use of equity in licensing through the AUTM annual survey (AUTM, 2011). Institutional characteristics such as the influence of a medical school on startup formation is ambiguous, some studies indicate the presence of a medical can have a positive influence on startup formation (Markman, et al., 2004), and use of equity (Feldman, et al., 2002); while others find little significance upon startup formation (Chukumba & Jensen, 2005; Jensen & Jones, 2011). Jensen and Jones (2011) also find that private and land-grant institutions form less startup companies

than public universities in their analysis of total startup formation from all universities reporting to AUTM 1990-2008. The size of the endowment, as a measure of wealth of the university is positively correlated with university startups reaching public status (Powers & McDougall, 2005a). The levels of federal research also have positive relationships with startup formation (O'Shea, et al., 2005; Jensen and Jones, 2011), and use of equity in licensing (Bray & Lee, 2000; Feldman, et al., 2002; Markman, et al., 2004). The level of industry funding at the university is positively correlated with startup formation (O'Shea, et al., 2005; Powers & McDougall, 2005a; Chukumba & Jensen, 2005; Jensen & Jones, 2011) and promotes the use of equity as well (Feldman, et al., 2002). The level of invention disclosures in the technology transfer pipeline has a positive influence on startup activity and use of equity (Bray & Lee, 2000; Friedman & Silberman, 2003; Chukumba & Jensen, 2005, Jensen & Jones, 2011). University policies and support for startup formation are also influential; the ability to use equity in licensing can support startup formation (DiGregorio & Shane, 2003), and university policies oriented towards startup licensing can positively influence IPO events (Powers & McDougal, 2005b). Faculty incentives in royalty rate sharing have a negative correlation with startup formation (Markman, et al., 2004, Markman, et al., 2009), suggesting higher royalty sharing rates may be a disincentive for entrepreneurial engagement. Faculty quality facilitates startup formation (DiGregorio & Shane, 2003; O'Shea, et al., 2005; Powers & McDougall, 2005a; Chukumba & Jensen, 2005; Markman, et al., 2009; Jensen & Jones, 2011), and faculty size can have a positive influence on startup formation (Powers & McDougall, 2005a; Jensen & Jones, 2011). Experienced TLOs form more startups (O'Shea, et al., 2005; Powers & McDougall, 2005a & 2005b; Chukumba & Jensen, 2005; Markman et al., 2005a; Markman et al., 2009; Jensen & Jones, 2011) and have higher use of equity (Friedman & Silberman, 2003; Feldman, et al., 2002). Larger TLOs use more equity (Bray & Lee, 2000), and can have a positive influence on startup formation (Markman, et al., 2005; O'Shea, et al., 2005; Markman, et al., 2009; Jensen & Jones, 2011). Experience levels of the TLO in working with previous licensing is negatively correlated with equity use (Feldman, et al., 2002),

suggesting that while age is positively correlated with equity use, prior engagement with licensing may lock-in a TLO to that commercialization path, and may be less willing to experiment with equity licensing. Previous success in working with startups can create a positive culture and influence upon subsequent startup efforts (Markman, et al., 2005b; O'Shea, et al., 2005; Jensen & Jones, 2011), and previous success with licensing inventions can also have a positive influence on startup formation (Chukumba & Jensen, 2005). Business competencies within the TLO, measured by Markman et al. (2004, 2009) as salary levels of TLO professionals, have a strong positive correlation with startup activity, suggesting those with a broad combination of skills in technology commercialization, marketing, IP protection, and licensing support university startup efforts. TLO structure influences a universities propensity to form startups and utilize equity in licensing. Feldman, et al. (2002), find a self-sustaining TLO utilizes less equity than TLOs less reliant upon licensing revenues to fund their operations. A traditional TLO structure takes longer to form startups (Markman, et al., 2005a), and uses lower levels of equity in licensing deals (Markman, et al., 2005b); whereas a for-profit TLO structure is correlated with both increased startups and use of equity (Markman, et al., 2005b). TLOs with more autonomy are also able to form more startups than those with less autonomy (Markman, et al., 2009). Licensing strategies of the TLO can influence outcomes: licensing for sponsored research and cash licensing strategies are correlated with less startup activity, while equity licensing is correlated with more startup activity (Markman, et al., 2005b). Finally, regional characteristics also have an influence upon startup activity from research universities. Industry research and development levels (Friedman & Silberman, 2003), venture capital availability (Bray & Lee, 2000; Powers & McDougall, 2005a), and the presence of a university related incubator (O'Shea, et al., 2005; Markman, et al., 2009) all have a positive relationship with startup formation. Chukumba & Jensen (2005) note that while venture capital availability has a positive relationship with startup formation, high interest rates for investment has a negative relationship, suggesting investors may look for more lucrative opportunities when returns are higher.

Continued analysis of these characteristics and their influence upon the academic technology transfer process and its outcomes will help those wishing to increase effectiveness in university technology transfer and stimulate entrepreneurial activities of faculty. An updated evaluation of the academic technology transfer process and outcomes can shed additional light on how characteristics of the university and TLO may influence licensing and startup efforts in the current environment.

Gaps for Further Analysis

Evaluation of technology transfer activities and outcomes in recent years can help to determine how university attributes in organization, policies, and TLO characteristics support the growing entrepreneurial activities in the university environment. As technology transfer efforts of research universities continue to grow across the US in response to expectations from national and regional policy makers and university administrators, other characteristics may be identified as having some influence upon technology transfer outcomes. From the studies included in this review, some gaps appear for further analysis. Many evaluate university policies, orientation and incentive structures for faculty entrepreneurship. The findings of negative relationships for inventor royalty sharing rates by Friedman & Silberman (2003) and Markman, et al. (2009) with licensing efforts, and startup formation (Markman, et al., 2004, Markman, et al., 2009) call for some additional analysis of drivers for faculty participation in academic entrepreneurship. Other university policies that govern faculty activities at research universities such as promotion & tenure policies can be analyzed for their potential influence on the technology transfer process, and faculty disclosure rates, licensing, and startup formation. If entrepreneurial activities do not factor into promotion and tenure decisions, monetary incentives may have little effect. This line of research may become more important as universities adapt promotion and tenure policies to recognize entrepreneurial activities and community engagement efforts of their faculty. Further review may help US research universities find the right balance of policies and organizational resources to incentivize the formation of startups (Markman, et al., 2004).

Friedman & Silberman (2003) suggest evaluation of other TLO organizational characteristics to extend the findings from their work, suggesting characteristics such as TLO funding and reporting structures, experience of the TLO director, and other regional characteristics. Markman, et al., (2005a, 2005b & 2009) evaluate TLO financial and autonomy structures for their influence on startup formation, and licensing revenues, and Feldman, et al. (2002) include self-funded TLO structures in their analysis on university equity use. Other TLO organizational characteristics that may influence goals and objectives include the reporting relationship of the TLO, as the office to which the TLO reports may wish to set strategic commercialization strategies, influencing the overall technology transfer process and its outcomes at the university.

Several have noted that TLO links to business networks and quality commercialization skillsets within the TLO are important in supporting entrepreneurial efforts of faculty (Powers & McDougall, 2005a; Chukumba & Jensen, 2005; Markman, et al., 2005a). Staffing practices and business commercialization skillsets of the TLO function within the university environment are required for successful commercialization efforts (Siegel, et al., 2003; Smilor & Matthews, 2004; Markman, et al., 2004; Markman, et al., 2005a, Markman, et al., 2009). Recommendations for increasing technology commercialization skills include devoting more university resources to hiring skilled licensing staff or training TLO staff for improved commercialization skillsets (Siegel, et al., 2003; Markman, et al., 2009). These studies each note a need for increased diversity in commercialization skills of the TLO to help identify the appropriate path for commercialization for academic innovations (whether licensing or startup), in addition to creating expanded networks with both entrepreneurs and industry contacts. Licensing capabilities, or access to a receptive industry network, shorten time to commercialization (Markman, et al., 2005a), and higher salaries of licensing professionals are positively related to startup formation and use of equity (Markman, et al., 2004, Markman, et al., 2009). Educational background and training of TLO staff and of the individual

tasked with managing the TLO may provide certain skills that can affect activities along the technology transfer process, providing opportunities for further analysis.

Table 2.5 summarizes the full set of the academic technology transfer papers analyzed in this literature review. As noted, these studies are specific to those which evaluated characteristics of US research universities, their TLO offices and their regions. This line of research on academic technology transfer efforts is often limited to evaluation of self-reported survey and observational data to establish correlations and efficiency rankings in academic technology licensing. The causal implications of university and TLO characteristics and resources, regional attributes, and licensing mechanisms will continue to be difficult to determine due to the nested environments and indeterminate direction of causality between dependent and predictor variables. Additional data can strengthen the research by providing new observations and units of analysis, but the causality issue will remain. Alternative mechanisms in licensing practices, organizational structures and other characteristics of TLOS, and university incentive policies (such as promotion and tenure incentives to faculty and incentives to TLO licensing staff as well as royalty distribution policies) will be important to continue to monitor for their influence and effectiveness in supporting the technology transfer process. Additional analysis will be informative as institutional leaders and directors of academic technology transfer activity at US research universities continue to respond to regional and national expectations for technology transfer and pressures for economic impact.

Policy Considerations

Implications of this review from a policy perspective are important for academic leaders, TLO directors, and other practitioners of technology transfer or economic development. The policy considerations from this literature review are many. US universities are increasing their resource commitment to their technology commercialization functions and supporting startups created for the commercialization of academic inventions, as noted by the increased levels reported to the AUTM annual licensing survey each year (AUTM, 2011; Kim, 2013). Anecdotal evidence and assumptions,

along with high profile news stories and patent decisions, can sway decisions on university technology commercialization strategies and allocation of resources (Blumenstyk, 2008). Studies utilizing strong research methodologies with valid statistical inferences can inform decision-makers on how certain characteristics of universities and TLOs may influence the technology transfer process. Information grounded in empirical data analysis can be used to provide insight into effective alignment of organizational structures and skillsets to support licensing activities and entrepreneurial faculty.

Invention disclosure, patenting activity, licensing and startup activities have all increased, as have revenue streams to universities from these activities. University administrators may wish to focus efforts upon specific commercialization outcomes; consequently an understanding of how university, TLO and regional characteristics may influence the academic technology transfer process provides information enabling alignment of characteristics to facilitate desired outcomes. University characteristics including faculty incentive policies, an entrepreneurial orientation of the university, faculty quality, amount and type of research funding, experience, and business capabilities of the TLO are all points to consider for universities evaluating their technology commercialization efforts for short and long term success. External characteristics such as venture capital availability and the concentration of related industry can be taken into consideration in developing policies regarding licensing, startup formation and the utilization of equity in licensing to startups.

Positive shifts in efficiency and productivity of university technology commercialization efforts may be due to growing receptivity to technology commercialization and academic entrepreneurship (Thursby & Kemp, 2002; Thursby & Thursby, 2002). While relative efficiency is volatile year to year, US universities are becoming more efficient in their use of resources to facilitate commercial outcomes (Kim, 2013). Technology commercialization activities are not solely determined by input/output measures however, and many other organizational and regional

characteristics of the university influence technology commercialization efforts beyond relative efficiencies.

Policies and procedures of the university supporting an entrepreneurial culture and invention disclosure are an important influence upon the commercialization process. Policies designed to attract and retain high quality faculty and support and incentivize entrepreneurial efforts can influence licensing activities, receipt of revenues, and startup formation. Royalty distribution policies can be balanced with other incentives if a university wishes to strategically influence a particular commercialization path (Markman, et al., 2005a). Providing appropriate organizational support, incentives and resources for the TLO in addition to training or hiring broad skills for the dual nature of licensing and startup formation, are all attributes that can be controlled at some level by research universities. Those under university control can be assessed for their alignment and support to the universities technology transfer goals, modifying those that make the most sense in light of institutional resources, goals and objectives, policies and procedures, and the regional environment in which they are located, where regional entrepreneurial, venture capital, industry R&D investment characteristics can all potentially influence the technology transfer process and its outcomes.

Table 2.5 Summary of Academic Technology Transfer Studies

Author(s)	Title	Goals	Data	Methods & DV variables	Findings
Bray & Lee (2000)	University Revenues From Technology Transfer: Licensing Fees vs. Equity Positions	Analyzes the financial return of universities' taking equity in their spin-off companies, and the prevailing attitudes toward taking equity. Compares differences in equity and direct licensing policies	Interviews with licensing managers at 10 U.S. university TLOs (seven private and three public universities).	Comparative analysis: DV: value of equity sold in spin-off companies compared to return on an average license.	Average value of equity sold from university startups companies, reduced by 50% to account for startup failure rate, is still more than 10 times the average annual income from a traditional license, and sig higher than the amount usually received as a license issue fee.
Thursby & Kemp, (2002)	Growth and productive efficiency of university intellectual property licensing	Model productivity change of technology licensing to determine whether increase is due to increased resource commitment to technology licensing or other factors	57 institutions over a 6 year period (1991-1996) from AUTM survey	Data envelopment analysis (DEA) & logit regression Outputs: disclosures, patent apps, industry sponsored research, licenses, & royalty income	Size of the TLO, federal research $, faculty quality and size influence efficiency & outcomes. Schools w/smaller available inputs are more efficient. Licensing growth due to changing entrepreneurial culture, & increased industry interactions.
Thursby & Thursby (2002)	Who Is Selling the Ivory Tower? Sources of Growth in University Licensing	Growth in invention disclosures, new patent applications and licensing agreements are modeled to identify sources of growth Asks if growth in invention disclosures may be due to reorientation of research faculty away from basic to applied	64 universities, DVs and IVs from 1994-1998 obtained from AUTM	DEA: 3-stage process 1. Disclosures; federal and industry research $, size of TLO are resource inputs. 2. Patent applications; disclosures and faculty quality are inputs, 3. Licenses; disclosures, patent apps are inputs	Increased willingness for faculty disclosure, & university to patent (not reorientation of research), as primary sources of growth. Increased inputs w/o corresponding growth in Licensing TFP may be due to licensing lag or diminishing quality of disclosures.
Feldman, Feller, Bercovitz, & Burton (2002)	Equity and the Technology Transfer Strategies of American Research Universities	Evaluates the intensity of a university's equity interests, related to behavioral and structural variables,	Survey of 124 Carnegie I and II research universities, verified by AUTM Survey. Responses from 67, Model N=62	Lower-bound TOBIT model to estimate the use of equity as a function of the university's own technology-transfer experience. DV % of equity investment: total# of equity interests divided by total active licenses through 1998	Growth over time in university use of equity in licensing – 1978 earliest date, in 1994 40% of respondents had taken equity and in 2000 70%. Prior experience (TLO Age) positively related to the use of equity - older TLOs have greater use of equity. Cumulative licensing experience has a nonlinear relationship - universities appear more likely to use equity as they gain experience; but use decreases with high licensing activity. Self-supporting TLO is correlated with lower equity use

Table 2.5 (*continued*)

Author(s)	Title	Goals	Data	Methods & DV variables	Findings
Siegel, et al, (2003),	Assessing impact of organizational practices on the relative productivity of university technology transfer offices	Evaluate differences in university cultures, motives and incentives; and whether they contribute to capacity differences in technology transer, relative performance in technology transfer may depend on organizational practice	Data for 80 US institutions from AUTM, 91–96, with interviews with 55 technology transfer stakeholders, and NSF and the BEA	(SFE) Cobb-Douglas form Licenses and $ = outputs Disclosures, TLO size, legal $ = inputs. Environ. factors: public and medical school indicators; TLO age. Regional: industry R&D intensity and state GDP	Technical inefficiency comes from environ and organizational characteristics Invention disclosures critical. TLO size facilitates licenses. Legal expenditures negatively related to licenses, positive for royalty revenues Environ: Older TLOs have higher revenues. Regional industry R&D density increases licensing.
DiGregorio, & Shane (2003)	Why do some universities generate more start-ups than others?	University Policies (equity, royalty incentives),Incubator and Industry Research funding examine effect of MACRO-level factors that vary across universities over time on rate at which new firms are created to exploit university inventions	AUTM startup activity from 1994 - 1998 for 116 universities, Venture Economics, Gourman Reports, USPTO, surveys	Negative Binomial models in generalized estimating equations for panel repeated measures over multiple years DV: # of startups from a given university over a 5 year period	University policies - , & university's intellectual eminence, taking equity in lieu of IP and licensing costs, & low inventor's % of royalties positively affects startups. Find no effect on availability of VC availability in regional MSA or presence of university affiliated incubator, & limited support for commercial orientation of university research
Friedman & Silberman (2003)	University Technology Transfer: Do Incentives, Management, and Location Matter?	Determine characteristics of research universities that influence Invention Disclosures submission, and evaluate influence of university policies and incentives, regional and local characteristics that affect licenses, startups, and use of equity	86 universities 1997-1999 for invention disclosures (AUTM) Annual Licensing Survey for data on the university technology transfer outputs, Milken Inst. for Tech-Pole Index	Linear regression, 2-equation recursive system: 1st DV=Disclosures (ID), as a primary input into 2nd equation DVs= licenses, start-ups, revenue, licenses with equity in 1999 N=86, single year	Faculty quality, # of departments, federal research & industry research funding all positively influence invention disclosure submission. Previous disclosures, TLO Age, and Tech-pole index are strong influence on licenses executed in 1999 and on equity use in those licenses. Royalty sharing with departments is a negative influence on 1999 licensing activity. TLO Age and Tech-pole index positive influence on startups

Table 2.5 (*continued*)

Author(s)	Title	Goals	Data	Methods & DV variables	Findings
Markman, Gianiodis, Phan, Balkin (2004)	Entrepreneurship from the Ivory Tower: Do Incentive Systems Matter?	Determine whether incentive systems—monetary payments to inventors, their department or institution, or to university technology licensing office (UTLO) personnel—affect entrepreneurial activities at U.S. universities.	128 US universities, 1999 outcomes Data from AUTM Licensing Surveys (1999, 2000), interviews with UTLO directors, web-based searches of each UTLO's institution, and the USPTO	Hierarchical regressions for each DV. 1st step: TLO age, research grants, and medical school. 2nd tested faculty and depts' incentives, TLO pay. DV: 1999 entrepreneurial activity (1) # equity licenses, (2) # of university business incubators, & (3) # startups. N=128	Research dollars stimulate entrepreneurial activity. TLO age significant and unexpectedly negatively related to equity licenses & startups, payment to faculty departments not significant. Monetary incentives to scientists are significant but negatively related to the number of equity licenses UTLO salary is significantly and positively related to the # of equity licenses and to the # of new ventures
Smilor & Matthews (2004)	University Venturing: Technology Transfer and Commercializatio n in Higher Education	Identify forces and factors that have an impact upon technology transfer and commercialization activities from a set of peer institutions & identify best practices.	Interviews with reps and TLOs from 5 leading universities known for economic development impact and successful licensing, startup activity and use of equity	Qualitative Comparative Study - "best practice" institutions with regional impact DVs: TLO(budget, staff, $, #licenses, #startups, equity use) royalty distribution	Strong leadership and commitment to role of university, unequivocal and substantial support for TLO, faculty recognition and rewards for entrepreneurial behavior all have a positive influence on university's commercialization capabilities. TLO has dual focus - startups & licensing, needing skills in both areas. TLO will benefit from staff with commercialization skills & knowledge of university research. Links to bus development orgs are key
O'Shea, Allen, Chevalier, & Roche (2005)	Entrepreneurial orientation, technology transfer and startup performance of U.S. universities	Link attributes of University resources and capabilities, institutional, financial, commercial and human capital to university startup formation.	141 US Universities 1995-2001 (AUTM, faculty quality from NRC, R&D funding from NSF, Center Institute for University performance, Milken Institute, USPTO)	Random Effect negative binomial method DV: yearly # of startups Controls: Med school, Institution type, industry infrastructure, endowment funds	Tradition and history of TLO with previous startup activity, faculty quality, commercial capability Size of TLO and amount of science & engineering research funding are positive predictors of startup activity Not sig: public/land grant/medical school/endowment size/incubator/regional knowledge infrastructure

Table 2.5 (*continued*)

Author(s)	Title	Goals	Data	Methods & DV variables	Findings
Powers & McDougall (2005a)	University startup formation and tech licensing with firms that go public: a resource-based view of academic entrepreneurship	Relationship between level of industry research funding, faculty quality, patent importance, age of the technology office, and venture capital of a geographical area to # of start-up companies and # of IPO events.	multiple archival sources on 120 institutions 1996-2000 classified as Research extensive and research intensive, SEC for IPO events	Negative Binomial N=120 (1996-2000) DVs: TOTAL # startups (1996-2000) (AUTM), & TOTAL # of IPO events (1996-2000) (SEC)	Previous (93-95) levels of industry funding, faculty quality (93-95 citations), have strong influence on subsequent Startups and IPO events. Larger faculty size influences startups, & endowment influences IPO events Age of TLO strong positive influence on startups, somewhat with IPOs; level of VC in MSA also a positive predictor of both startup and IPO events
Chukumba & Jensen (2005)	University invention, entrepreneurship, and start-ups	Determine factors related to commercialization. Evaluates characteristics of inventor, the TLO, invention, and the regional financial market.	AUTM licensing surveys for 1993-2002. 110 Universities, Panel, measures for each year: University i, in Time t.	Negative Binomial N=951 DVs are # of startups and licenses Private/Med school indicators not significant, size of TLO not significant	# of disclosures has strong influence on licensing & startups – larger # disclosures increases commercially viable pool Past success (gross royalties) increases subsequent successful licensing AGE of TLO, ratio of industry/fed res$ & Inventor quality are positive influences on licensing, & startup activity Access to VC stimulates startups Interest rate & returns to VC have negative correlation with startup activity
Powers & McDougall (2005b)	Policy orientation effects on performance with licensing to start-ups and small companies	Evaluate university support & policy orientation towards licensing to startups/small companies or established firms, and interactions with regional entrepreneurial environment. Evaluates support policies (TLO & Licensing staff), selectivity policies, regional R&D activity and venture capital accessibility	134 US research universities (1996 - 2000) AUTM Survey (2003) IPO events from prospectus filings - SEC.	Hierarchical moderated regressions to test interactions between policy orientation and support of startup activity, & regional financial environment. DVs: Log Average IPO events (96-00) from licenses with small companies, & Log Avg revenues (99-00)	TLO age and faculty quality are extremely important for IPO and royalty income. University selectivity and regional entrepreneurial density significant positive predictors of IPO events. Univ. policies orientated in support of entrepreneurial activity & licensing to small companies stimulate more startups. Universities located in entrepreneurially dense environments have larger portfolios of IPO companies.

Table 2.5 (*continued*)

Author(s)	Title	Goals	Data	Methods & DV variables	Findings
Markman, Gianiodis, Phan, & Balkin (2005a)	Innovation speed: Transferring university technology to market	Evaluate time/speed to technology commercialization, and whether shortened commercialization time is associated with more positive outcomes (higher revenues and # of Startups). Determine importance of TLO structure, inventors, firms, degree of collaboration, and business competencies of TLO	Structured interviews with 91 TLO directors AUTM data validated by interviews.	Path Analysis with hierarchical regressions: N=91 DVs: Logged # of startups & Logged revenues (2000 & 2002)	Commercialization time significant: Inventor involvement/engaged faculty & TLO competency shorten time; complexity in collaboration increases time. Larger TLOs are better at startup formation, Traditional TLO structures has increased time to startups, less effective at generating revenues and startup formation, while for-profit decreases time to startup compared to non-profit structure.
Markman, Phan, Balkin, Gianiodis, (2005b)	Entrepreneurship and university-based technology transfer	Which TLO structure and licensing strategies are conducive to startup formation? How are these related to each other? Evaluates TLO Financial structure (**Traditional** unit within university, **non-profit** separate entity, or **for-profit** focused on venture creation) And TLO Licensing strategies: for sponsored research, cash licensing and equity licensing	Data from interviews with 128 university TLO directors in 2002 & content analysis of university policies	Grounded theory: Long interviews, defining characteristics most likely to lead to startup formation N=128 DV = Startups in 2002 Used correlation matrix to identify linear relationships between TLO structure, licensing strategies, and startup formation	Previous experience with startup activity has strong positive influence Traditional TLO structure: no correlation with startup, but likely to use equity, more likely to license for sponsored research; Non-profit (501)c3: no correlation with startup activity, less likely to license for sponsored research; For-profit: strongly correlated with startups & equity. TLO licensing strategies: Sponsored research & cash licensing have negative correlation with startups Equity use positively influences startup formation.
Thursby & Thursby, (2007)	University Licensing	Evaluating the rational and goals behind university patenting and licensing efforts; the stage of academic inventions being licensed, the role of inventors; licensing practices of universities, and revenues generated from technology transfer activities	Data from AUTM 2004 survey and a supplemental survey of 65 TLO directors and 112 licensees of university inventions.	OLS & Quintile tables. DV = Licensing revenue Logistic regression to evaluate inventor & university attributes on disclosure activity DV=1 if inventor disclosed	# of Licensing professionals in the TLO, # of previous licenses generating income & research funding levels of the university all have a significant relationship in revenue generation of the TLO. Additional research funding increases disclosures, industry funds have strong influence on both disclosure & licensing More disclosures come from engineering than biosciences, from inventors with higher publications, high funding levels, inventors more likely to be male

Table 2.5 (*continued*)

Author(s)	Title	Goals	Data	Methods & DV variables	Findings
Markman, Gianiodis & Phan (2009)	Supply-Side Innovation and Technology Commercial-ization	Explain technology commercialization outcomes as a function of TLO licensing strategies, the structure of the TLO, and incentives for scientists, departments, and TLO staff.	Data from licensing surveys, interviews with 128 TLO directors in 2002 AUTM (1999, 2002) Licensing Surveys; formal policies and statistics	Hierarchical regressions Two DVs: Average annual licensing revenues (1999-2002), Average number of yearly spinouts from technology transfer activities (1998–2001)	TLO age: positively related to startups Size: greater revenues & firm creation Incubator: facilitates startups, Faculty quality: positive for revenues & startups Licensing for sponsored research negatively related to licensing revenues **TLO Structure:** low-autonomy negatively related to $$, ns for startups; high-autonomy significantly & positively related to startups, not revenue Incentives: inventor incentives negatively associated w/ $$ & startups, TLO pay signif & positively related to startups
Bulut, H., & Moschini, G. (2009).	US universities' net returns from patenting and licensing: A quantile regression analysis.	Assess potential of US universities in generating revenues from licensing activities given university characteristics	148 US universities from 1998 to 2002, aggregated at the university level, using annual averages of the time-varying variables	OLS & Quantile regression: Methods used to model and estimate net licensing revenues as linear functions of a set of characteristics of the university, faculty & region. DV = net revenues	Public/Private/Medical: Private universities with a medical school obtain significantly higher returns than public without medical school (up to 2.5X) Research Size significant influence on licensing revenues (all but lowest quantile) Log of Faculty quality (citations) – not significantly correlated with net revenues Local industrial R&D – not strongly significant except for universities at high end of revenue distribution
Jensen & Jones (2011)	University Startups and Entrepreneurship: New Data, New Results	Evaluating how university entrepreneurship has changed from 1994 to 2008. Evaluating importance of university, department and regional characteristics, prior experience with startup formation	AUTM data – all universities that reported to AUTM Licensing Survey from 1994 – 2008.	Negative binomial with random effects, Poisson and Logit methods as benchmarks DV = Startups 1994-2008 N=912 with full model	Academic entrepreneurship expands in tough economic times. Quality of engineering, size of biological faculty are important after 2000 Size of TLO has significant impact upon startup formation, an additional employee increases startup activity by about 7% Hurdle – prior experience with startup activity has strong influence upon subsequent startups – those with prior experience may have startup rate 1.5X greater than those universities without prior experience

Table 2.5 (*continued)*

Author(s)	Title	Goals	Data	Methods & DV variables	Findings
Kim, (2013)	The Ivory tower approach to entrepreneurial linkage: productivity changes in university technology transfer	Evaluate whether growth in government funding for academic research (which increased by 50% from 1998-2008) corresponds to an increase in efficiency in academic technology transfer activities.	Panel data for 90 universities (1999-2007) obtained from AUTM annual licensing survey	DEA –to estimate relative efficiency across universities. Invention disclosures, federal and industry research expenditures, TLO size = inputs Issued US patents, licenses, and license income = outputs	Upward trend in efficiency growth: average TFP growth of 31% over 9 years Licenses grew avg of 4%/year, licensing income 28%/year, and patents remained steady. Universities vary in efficiency. inputs also increased; licensing staff grew an average of 11%/year, indicating growing commitment of resources Medical Schools & Private schools not as significant to TT activities as in past

Chapter 3. Collaborative Technology Transfer: A History of North Carolina's Triangle University Licensing Consortium

Introduction

The Triangle University Licensing Consortium (TULCO) is an early example of three Research Triangle Park (RTP) universities (The University of North Carolina at Chapel Hill (UNC), NC State University (NCSU), and Duke University) and working together to increase commercialization capacity and enhance technology transfer activities.[7] University system and community leaders formed a TULCO governing board in 1986 to expand technology-licensing capacity, enhance entrepreneurial culture at the universities, and increase engagement in the RTP. The consortium's formally operated from 1988 through 1995, and it helped each of the Triangle Universities attain these goals. This paper documents TULCO's history, organizational structure, mission and goals, and overall outcomes of the consortium in licensing the inventions developed from academic research. This early experiment among these three regional research universities provides a potential model for other research universities considering pooling resources and working together to enhance technology commercialization. This case study attempts to discover why the three triangle universities decided to collaborate in a technology licensing consortia and how they set up that effort, how effective the consortium was in effecting the entrepreneurial cultures of the universities and licensing university inventions, and finally, why the consortium was disbanded.

The history behind the formation of the consortium is evaluated in order to determine why the three regional universities decided to collaborate through a single licensing entity. To assess the

[7]The term 'technology transfer' is defined as the efforts undertaken towards converting academic and research based inventions into marketable products and services through licensing to industry or a university startup. These activities encompass applications for intellectual property protection, networking with industry contacts, market research, and license negotiation.

effectiveness of this early collaborative effort among the Research Triangle universities in expanding technology commercialization activities, the consortium is evaluated for its impact upon the licensing activities amongst the three universities, whether it had an effect upon the entrepreneurial culture within the universities through increased patent activities, and if the consortium helped the three universities expand networks with industry.

A compelling case is found in support of technology licensing consortia where there is limited existing commercialization capacity at research universities. TULCO's history suggests that regional consortia can help to affect the internal entrepreneurial cultures, build capacity, create efficiencies, and expand industry networks for the universities involved. For universities without a strong internal entrepreneurial culture and existing infrastructure for technology licensing and commercialization, a consortium with others who have similar objectives and constraints can have a positive impact on technology transfer activities. The lessons learned from this study provide recommendations for future multi-university technology commercialization consortia.

The remainder of this paper is divided into the following sections. National policies influencing the development of intellectual property at US research universities is presented, with recent calls for collaboration among universities at the federal levels. The theoretical background and framework on institutional organization, history, and culture is reviewed, which provides the motivation for the research questions going into this case study analysis. The subsequent section discusses the history around early technology transfer, the initial formation of TULCO and review the resources allocated to its operations. The disbanding of TULCO's operations is discussed and the adoption of the marketing and licensing function in house by each institution. The institutional cultural differences and TULCO's resource constraints are reviewed for their impact on the consortium's dissolution. The case study methodology is presented, followed by an analysis of TULCO's activities and a discussion of the trends that data might represent. Information collected from interviews and discussions with key individuals supplement the data, and provide additional information on the consortium's disbandment. A summary of the key findings from this case study is

presented, with an analysis of the pros and cons of the licensing consortium model. Key policy recommendations are presented with suggestions for research universities who may be considering this type of organization as a way to develop or enhance their existing technology licensing and commercialization efforts.

National Policies

The United States government has implemented several national level policies to enhance and promote technology transfer from its national labs, expand the use of government funded technologies (Bayh-Dole Act, P.L. 96-517, 1980), promote and encourage cooperation between universities and federal laboratories (National Cooperative Research Act, P.L. 98-462, 1984, 1993), and support small business's efforts in research and development and licensing technology under the Small Business Innovation Development Act (P.L. 97-219, 1982), which requires federal funding agencies to set aside 2.7% of their external funding budget to support small business engaging in research or research & development (NIH, 2013).[8] The policies established in the 1980's specific to technology transfer efforts of US research universities have had a significant impact upon university patenting and licensing activities, and are increasing as the entrepreneurial culture expands within the academic environment (Bozeman, 2000, AUTM 2011).

Bayh-Dole Act, (P.L. 96-517)

Enacted in 1980, the Bayh-Dole Act, (P.L.96-517) gave the universities the right to retain title to inventions created through research activities, and was designed to facilitate technology licensing and public utilization of inventions developed from federally funded research. The US research universities were permitted by this Act to hold title to these federally funded inventions, provided they engaged in best efforts to commercialize those inventions (P.L.96-517). The universities were expected to be more effective in translating the inventions and innovations into

[8]See Bozeman, B., (2000) for a comprehensive list of major technology policy legislation 1980-1990.

public use. After the passage of this Act in 1980, US research universities began to increase their internal capacity for technology licensing and transfer and support of entrepreneurial activities (Nelson, 2001; Mowery, et. al., 2001; Shane, 2004). Now some thirty-three years after the passage of that act, critical evaluations of the impact of the Bayh-Dole Act recognize its success, but also suggest a need to further enhance and facilitate those activities by developing alternative forms of service and support to the universities and the scientific researchers supported by federal grants (Nelson, 2001; Sampat, 2006; Rothaermel, et al., 2007). Discussions are taking place across the US on finding alternative mechanisms to efficiently and effectively stimulate technology transfer and commercialization of scientific research for the benefit of society and regional economic development (Litan & Cook-Deegan, 2011). Siegel, Veugelers and Wright (2007) suggest the development of regional collaborations as one way to effectively leverage available resources for institutions that may not have a critical mass of research excellence and academic technology licensing expertise.

Kaufman Foundation

As part of those discussions taking place around the facilitation of academic technology transfer, the Kauffman Foundation has also proposed some alternatives, which include the creation of multi-university commercialization consortia to enhance academic entrepreneurship and create economies of scale. Kauffman researchers acknowledge the inherent difficulties due to lack of capacity and limited resources in technology licensing and commercialization efforts at smaller US research universities. The broad spectrum of specialized expertise required to commercialize the variety of academic inventions requires an investment in resources and specialized skillsets not possible at some schools (Litan & Cook-Deegan, 2011). It's doubtful that any single technology licensing function will have personnel with a broad enough domain expertise to have knowledge of every area of research without having a large pool of technology licensing staff members. By combining resources in a consortium, regional universities could increase their domain of expertise and skillsets, potentially realizing greater efficiencies and economies of scale.

Current Federal Initiatives

This consortium model proposed by the Kauffman Foundation was included in two bills proposed to the 112th congress during 2012: the Startup 2.0 Act (S.3217), and the America Innovates Act (H.R. 4720). While both of these bills died in committee, they represent a desire to enhance entrepreneurial activities among the research universities across the nation. The Startup Act has been resurrected in a 3.0 version of the bill submitted to congress February 13th and 14th of 2013,[9] and has an entire section devoted to the "accelerated commercialization of tax payer-funded research" (H.R.714 and S.310), which authorizes a grant program through a diversion of a small percentage (0.15%) of federal research funding agencies' budgets specifically for the acceleration of technology licensing and commercialization of federally funded academic inventions. These funds are to be awarded yearly to institutions of higher education, "including consortia of institutions of higher education," for programs and initiatives designed to improve commercialization and transfer of inventions from research (H.R.714). Proposals for these funds must demonstrate a "capacity for accelerated commercialization, proof of concept proficiency, and translating scientific discoveries and cutting-edge inventions into technological innovations and new companies" (H.R.714). Of particular interest are programs that could be replicated by other institutions of higher education if proven to be successful. The current versions of this bill have been referred to committees for evaluation.

The America Innovates Act of 2012 (H.R. 4720)[10] introduced in 2012, was to establish a 'Bank' directed to promote commercialization efforts of science and engineering inventions; providing grants, loans, and other assistance to eligible entities and individuals. The bank would have provided investment funds to eligible entities and individuals, including consortia of institutions.

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[9]A Bill introduced to the House of Representatives by Rep. Michael Grimm (R-NY) and Senator Jerry Moran (R-KS). The 2012 bills died in committee, and have been reintroduced as H.R. 714 and S. 310, Startup Act 3.0, presented to the 113th congress February 2013 http://www.govtrack.us/congress/bills/113/hr714, and http://www.govtrack.us/congress/bills/113/s310

[10]A Bill introduced to the House of Representatives by Representative Rush Holt (D-NJ) in 2012 "To establish the American Innovation Bank, to improve science and technology job training, to authorize grants for curriculum development, and for other purposes." Legislation died in committee.

Each of these proposals submitted to the US congress are designed to facilitate the commercialization of inventions from federally funded research by expanding programs and entities, including the creation and support of university technology licensing consortiums.

The existing framework established in response to the Bayh-Dole Act has created an environment where universities are expected to engage in entrepreneurial and technology transfer activities. The additional recommendations put forward by the Kauffman Foundation are found in additional legislation being considered at the national level, and while these particular pieces of legislation did not move out of committee, they represent the desire to help academic inventions reach their applied outcomes more effectively and efficiently. The information from this analysis of an early stage licensing consortium can provide further evidence of how these collaborations can facilitate the commercialization activities of universities.

Institutional Organization, History, and Culture

"History matters… present and future are connected to the past by continuity of a society's institutions" [11]

Previous academic research evaluating institutional organization, history, and culture provide a theoretical framework for the analysis of this early stage licensing consortium. TULCO evolved both in response to a growing regional need in the research triangle area, and the growing national incentives around technology licensing and commercialization from US research universities in the 1980s. Regional and national expectations regarding the roles of academic research universities have continued to expand across the nation and globe, with universities becoming much more regionally engaged, expanding their technology commercialization efforts (Bercovitz & Feldman, 2006).

[11]North, 1990, Institutions, institutional change and economic performance, Cambridge, MA: Harvard University Press, p. vii

Douglass North's (1990) seminal work on institutions, institutional change and economic growth developed a framework demonstrating how institutional historical, environmental, and regulatory forces work to shape behavior and the direction of change of institutions, suggesting institutions change incrementally in response to economic incentives and performance. Formal forces and structures (legal and government regulations) and informal behaviors (norms, values, and beliefs) govern the institutional perspectives that act to shape behavior (North, 1990). Regional and national institutional frameworks have an impact upon the innovation processes of institutions (O'Shea, et al., 2008). Developing an understanding of the environment in which institutions reside and in which new ones are created becomes fundamental to understanding their development and growth, and their potential demise.

Partnerships among research universities may facilitate technology commercialization efforts and outcomes by providing access to and leveraging additional resources. Partnerships among universities in consortia or otherwise provide an expanded network for technology licensing and commercialization of academic inventions (Litan & Cook-Deegan, 2011). Closeness in industry-university partnerships is developed through joint ownership of IP, co-location within a region, a long, stable history of interaction, further underpinned by institutional commonalities among participants, encouraging shared norms, attitudes, values and expectations across the partnership (Asheim & Coenen, 2006). Suggesting any type of technology licensing consortia may benefit from common norms, attitudes and expectations among the universities involved. Technology licensing and commercialization is a 'contact sport;' as such, it is quite important to build relationships and expand personal and professional networks to effectively commercialize inventions (Carlsson & Fridh, 2002). Technology licensing consortia among universities may facilitate relationship building in addition to combining and leveraging resources for effective technology licensing. Linkages among the national innovation and business systems and regional innovation systems all influence the long-term technology licensing strategies of research institutions (Asheim & Coenen, 2006).

These prior studies provide the foundation and framework for this analysis on the technology licensing consortium among Duke, NCSU and UNC. They suggest that a strategic focus upon creating licensing consortia with appropriate resources among regional research universities may facilitate capacity building and long-term success in technology commercialization efforts.

History of TULCO

Early Technology Transfer Efforts

In the years following the passage of the Bayh-Dole Act on December 12th, 1980 (P.L. 96-517)[12], leaders of the UNC system and the Research Triangle recognized that inventions generated at the triangle universities lacked identifiable commercialization pathways, or effective mechanisms for getting these inventions to industry and thus into public use (Little, 1986). There was a general lack of knowledge on which industries might be interested in the research outcomes (Fordham, 1985), and without an established industry network, no mechanism existed to develop that knowledge. Siegel, Waldman, Atwater, and Link note that technology transfer activities are those that "facilitate commercial knowledge transfers through the licensing to industry of inventions or other forms of intellectual property resulting from university research" (Siegel, et al., 2004, p 116). Little capacity existed at the triangle public universities to facilitate these types of activities at the time, and their leaders were committed to building this capacity.

UNC System President William Friday established a technology transfer committee in 1983 to evaluate the existing technology transfer efforts of the UNC system's institutions as a way to grow support for scientific research and expand upon university outreach and public service efforts (Fordham, 1985). The Technology Transfer Committee, with support from the UNC General Administration and the Microelectronic Center of North Carolina (MCNC – a quasi-public technology development organization in the Research Triangle), commissioned a study from

[12]For a thorough discussion of the Bayh-Dole Act, see http://www.autm.net/Bayh_Dole_Act1.htm

Cambridge Associates Inc. in September of 1984 to evaluate and make recommendations towards improving the effectiveness of technology transfer activities at the UNC system schools. The scope of work written by this committee for the consultant's study noted:

> *"The development and transfer of technology are important to the constituent universities and to society because they result in the development of new products and the enhancement of existing ones, facilitate the creation of jobs, improve productivity, and provide the foundation for additional research. The University institutions are therefore committed to encouraging the diffusion of the technological innovations from their laboratories to the marketplace through direct research relationships with the industrial community and through effective transfer of the products of their research to the public.*[13]"

Resources committed to technology transfer efforts at the public research universities in the Research Triangle region lagged behind similar research institutions (Clough, 1985). The UNC institutions were understaffed; benchmark institutions utilized in the study for comparison maintained at least one full-time professional staff member for technology licensing activities per $40-60 million in research funding dollars.[14] The two UNC research campuses located in the triangle area, with research funding between $54-75 million in 1984 (NSF WebCasper, 2013), each had a single individual investing only 50% of their time towards technology transfer activities (Clough, 1985).

UNC and NCSU were building their technology transfer capabilities, and Duke had a small but established program (Fordham, 1985). NCSU, with a strong engineering program, had started some technology transfer efforts in 1982, formally establishing an internal office in 1984, when the

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[13]Clough, Thomas N. (1985) *The University of North Carolina Technology Transfer Study*, Pub., Cambridge Associates Incorporated, 1985, p. 6

[14]Stanford University was utilized by Cambridge Associates as a benchmark for comparison, as they had committed solid resources to their technology transfer operations at the time of this study. The level and quality of sponsored research, their network of industry relationships, entrepreneurial approach to licensing, specialization of TLO staff, industry aided evaluation of inventions, and the promotion and support of these activities from university leadership all contributed to Stanford's successes in licensing research-based technologies (Clough, 1985). Strong differences existed between Stanford's environment and that of the triangle universities, most notably in levels of research funding and interactions with industry. Stanford also had less organizational constraints in working with industry than those faced by the public universities of the Triangle.

consortium was being considered.[15] UNC, the public flag ship of the university system, hired a lawyer within the sponsored research office in 1985 to support patent protection activities, but had no internal technology marketing or licensing capabilities.[16] Duke University, a private university with engineering and medical schools, had some internal technology transfer capabilities (e.g., patenting activity starting as early as 1974) due to engaged faculty and established industry research relationships. Duke committed a full time individual to technology transfer activities in 1985 according to AUTM, and formally established and fully staffed an office 1986-87.[17]

Cambridge Recommendations

The Cambridge Associates Report: *The University of North Carolina Technology Transfer Study*, provided several recommendations to help improve the technology-licensing capabilities across the 16 constituent institutions of the UNC system, focusing upon the two largest, UNC and NCSU. The findings of this study highlighted the nascent entrepreneurial culture and limited infrastructure supporting technology commercialization at the two public universities. Policies and procedures had been established for disclosing inventions, protecting intellectual property, and ensuring compliance with federal regulations. Patent committees at each of the universities provided open, visible mechanisms for decision making on intellectual property protection; and royalty-sharing policies with inventors had been established (Clough, 1985). Barriers to commercialization of research based inventions at the universities included a lack of effective marketing resources or capabilities within the institutions, an absence of a "culture of technology transfer" (i.e., relationships

[15]The Association of University Technology Manager (AUTM) Database from annual surveys of US research universities (for years 1991-2011) asks in which year the university hired a full time professional dedicated to technology transfer. This database has two dates for the start of NCSU's Technology transfer Office, 1982 when some technology transfer activities started, and 1984 when their first full-time Director was hired, per interview discussions.

[16]AUTM's database has UNC Chapel Hill's start date as 1985; when they hired counsel to manage their patent portfolio. 1995 was when their first official Director of Technology Transfer was hired and a full office established.

[17]Reflecting two different dates in the AUTM database, 1986 being the year the office was fully staffed, per interviews.

between academic researchers and industry were minimal), an absence of a clear link to the missions of the universities, and no incentives for faculty participation (Clough, 1985, p.14).

The recommendations provided by Cambridge Associates included institutional level suggestions such as developing partnerships with industry and government to create new and enhanced products and services from academic research and to develop long-term collaborations with private industries to expand the "vitality and scientific quality" of university research (Clough, 1985, p.10). The recommendations included suggestions that the universities "avoid building rigid constraints into policies and procedures and … retain as much flexibility as possible in negotiating license agreements and industry-sponsored research contracts," while preserving the "integrity and quality" of research programs and minimizing potential conflicts of interest (Clough, 1985, p.22). A strong emphasis upon a research driven approach to innovation—the creation of new knowledge—must clearly remain the primary mission of the institution, with intellectual property creation a valuable by-product. In order to avoid conflict of interest, recommendations included that clear separation be maintained between university research projects and work done in collaboration with a company, recognizing the close ties with industry required to effectively commercialize inventions (Clough, 1985). Incorporating non-financial incentives and rewards in promotion and tenure metrics for entrepreneurial activities was suggested as a way to increase legitimacy with research faculty (Clough, 1985).

The relevance of these recommendations continues today for any institution wishing to enhance a culture of acceptance towards technology transfer. For the technology transfer functions specifically, the consultants recommended three primary quantitative objectives: 1) maximize the number of inventions that can be licensed or will result in industry-sponsored research, 2) maximize revenues derived from those licensed inventions, and 3) provide responsive service to the faculty and administration regarding any issues around the management of intellectual property belonging to the university (Clough, 1985). These three objectives were considered by the consulting group to be the primary goals of academic technology transfer efforts.

The consulting group proposed two alternatives for the institutions to consider in expanding their commitment to technology transfer activities: a) each institution could independently commit resources and efforts, or b) could combine recourses through a single entity. An independent approach at each institution would allow more direct administrative control and maximize contact and communication amongst research faculty, licensing professionals and internal patent offices. However, research budgets would only justify the hiring of a single licensing professional, limiting the scope of specialization and interaction with industry. Recognizing limitations due to culture, size, funding, and resources available to North Carolina's public research universities, the consultants noted that unless there was a pooling of resources, there would be an inability to achieve the degree of specialization required in staffing technology-licensing functions at the individual triad universities (Clough, 1985). A cooperative approach, combining resources with a single entity handling all invention disclosures, would allow for greater specialization of the licensing professionals who could focus efforts and build credibility with faculty and industry experts. This would lead to more effective marketing of inventions, efficient use of resources, and development of economies of scale in technology licensing activities (Clough, 1985).

A commercialization partnership would focus upon increasing licenses and options with industry partners; maximizing licensing revenues; expanding industry partnerships for research; and providing responsive service to faculty inventors and university administrators (Clough, 1985). The proposed cooperative entity would provide marketing and licensing services for the inventions developed from academic research, while the universities maintained intellectual property administration and management in-house. An internal intellectual property management office would emphasize the university's commitment to technology licensing and commercialization efforts to the research faculty (Clough, 1985). This cooperative licensing entity was expected to address the underdeveloped marketing and licensing capabilities of the universities and establish an effective mechanism for extending inventions developed from academic research activities to industry (TULCO Agreement, 1986). The consulting firm strongly recommended a 5 to 10 years commitment

to a technology licensing collaboration to build needed infrastructure, gain required levels of expertise, develop long-term partnerships, and properly evaluate outcomes (Clough, 1985).

Duke University's participation in any triangle licensing consortium was considered necessary by the Cambridge Associates group for successful implementation of a regional technology licensing partnership. "Cooperation among all three major research institutions in Research Triangle would provide even better opportunities for specialization," and take advantage of any additional linkages in research among the three (Clough, 1985, p.37). A licensing entity representing all three universities would draw upon the "national and international image of the Research Triangle", and provide a single, visible organization while increasing accessibility to university inventions (Clough, 1985, p.38).

With recommendations from their board in January of 1986, the administration of Duke University determined it was in their institutions best interest to participate in the cooperative licensing effort in its initial stages and committed to joining the consortium (McDonald, 1986). Forming a consortium including all three research institutions across the triangle provided access to funding from the Research Triangle Foundation, an organization formed in 1958 to manage and control land and resources associated with the Research Triangle Park, and distribute those assets to the three triangle universities for educational, research, and other purposes "for which said institutions were founded" (Link, 1995 p.78). The cooperative approach was expected to provide significant aid in the achievement of the universities' technology transfer goals as part of their research and public service missions. Additionally, the consortium could aid in enabling the universities and private industry to work together for the 'good of the public,' a major goal of the Research Triangle (Ehringhaus, 1986).

There were three primary operational objectives for the consortium: 1) interactions with faculty inventors to develop invention summaries; 2) marketing and licensing the research based inventions to industry contacts as each university's licensing agent; and 3) negotiations for technology options and license agreements in conjunction with university representatives (Fordham,

1985). Patents rights remained at each university, with each maintaining their own intellectual property policies. Each university continued to maintain internal operations to handle invention disclosure receipt, facilitate industry research agreements, manage patent application processes, and oversee distribution of any revenues. Authority for all decision making regarding allocation of resources and adherence to policy remained with each campus (Fordham, 1985). TULCO's staff could not approve deals without the express involvement of the university, whose representatives approved and finalized any license agreements.

TULCO Funding and Formation

The three leaders of the universities, Chancellor Bruce Poulton of NCSU, President H. Keith H. Brodie of Duke, and Chancellor Christopher Fordham III of UNC, formed a Board of Directors to establish the governance and oversight of the licensing organization. The Board comprised three members from each of the participating universities appointed by the President or Chancellor: a senior research officer or administrator, a faculty member, and a member from each university's legal counsel's office. Organized as a 501(c)3 organization, TULCO's operations were kept under the control of the universities by the appointed Board members. The Board placed the operations of TULCO under the fiscal and organizational policies of Duke University, taking advantage of its hiring, benefits, purchasing, and related systems (Little, 1986). This arrangement helped keep overhead costs to a minimum, providing cost-savings, and flexibility in administering funds and employment policies.

A funding proposal for the consortium was developed and submitted to the Triangle Universities Center for Advanced Studies, Inc. (TUCASI), an organization created by the Research Triangle Foundation and incorporated November 21, 1975 (Link, 2002) to support collaboration among the three universities and increase their participation and presence in the Research Triangle Park. TUCASI represented "the nation's first three-university corporation designed to plan and develop joint research and educational activities in a major research park whose creation was based

on the existence of nearby universities" (Link, 2002, p.73). TUCASI was focused upon increasing their participation and presence in the Research Triangle Park. As TULCO was a cooperative enterprise among the three triangle universities, the consortium fit with TUCASI's overall mission (TUCASI History, last accessed 2-11-2013). Duke's involvement with the consortium may have been strongly promoted due to the existence of TUCASI and its support of initiatives among the three universities. Duke's participation opened up a source of operating funds otherwise unavailable to the consortium. A five-year funding proposal was submitted in 1985 to establish infrastructure and provide for operational and employment funding for the consortium. TUCASI agreed to fund the first five years of operations at a rate of $360,000 per year, $1.8 million, and expressed willingness to provide funding for the subsequent five years at a more limited rate if needed. The leaders of all three of the universities anticipated that TULCO would need less financial assistance from TUCASI as proceeds received by the universities from TULCO's licensing activities increased over time (Fordham, 1985). The consortium was expected to provide significant long-run returns to the universities in the form of increased research relationships with industry, an expanded industry network, and additional capacity building for technology licensing.

On June 30th, 1986, an agreement was signed among the three universities formally constituting the licensing consortium "for the purpose of facilitating the licensing of intellectual property submitted to the consortium" by the three universities "and other non-profit educational, scientific and research organizations" (TULCO Agreement, 1986, p.1). This organization was formally named the Triangle University Licensing Consortium, and often referred to as TULC or TULCo in early correspondence and ultimately known as TULCO. The scope of TULCO's overall mission was limited, as the agreement specifically noted the consortium was being formed *solely* to provide technology licensing services for each of the three universities, enhance their existing internal capacity, and realize significant efficiencies and cost savings (TULCO Agreement, 1986). Duke served as the consortium's home university to "receive, hold, and administer the funds awarded by TUCASI (TUCASI Board minutes, 4-1986)." While recommended that the consortium also assist

other affiliated members of the UNC system with technology commercialization, initial operations were limited to the three research universities in the triangle to ensure establishment of the consortium as the primary licensing arm of the universities (TUCASI Board minutes, 3-1987).

From the outset, Duke's involvement with the licensing consortium was expected to be time-limited. Duke's president expressed the desire to be bound to the consortium for the initial five years of operations, reviewing their licensing needs independently of the other two universities at the end of that initial period.[18] Dr. Brodie expressed two objectives for Duke's cooperation with the proposed consortium: relief for the general fund used to manage their Patent Office, and improved professionalism and expertise in commercializing the inventions produced by their faculty.

Geographic Location

The Research Triangle Park, in central North Carolina and delineated by the three research universities, provided a unique opportunity to leverage their co-location within a region. The geographic proximity of the three had allowed inter-institutional collaborations and research partnerships among the three, providing a fairly stable history of interaction among research faculty, despite other competitions across the universities. This proximity to each other provided an important element for collaboration, the ability to develop face-to-face relationships and interactions between TULCO licensing staff, faculty, and industry contacts were an important aspect in being able to successfully license the academic inventions.

The Research Triangle Institute (RTI) in the Research Triangle Park, provided space for the consortium free of charge for occasional assistance with technology commercialization activities. The space provided by RTI comprised of three small offices for the licensing professionals, some administrative space, and a small conference room. This space was perfect for TULCO's inception, as it was centrally located to the three universities, limiting travel time to get to each campus, and

[18]Memorandum from H. Keith H. Brodie to TULCO's Board, 1-23-86

provided enough office space for TULCO's staff. Expansion, however, was not possible, and limited the consortium's ability to meet the growing needs of each university.

TULCO Operations

The Board hired TULCO's sole Executive Director Mr. William Riley, in April of 1987.[19] Riley immediately started outreach efforts and discussions with inventors at the three universities. Staffing levels for TULCO comprised the executive director, two associate directors, three licensing professionals, and two administrative staff members. With backgrounds in bioscience, materials, electrical and biomedical engineering, TULCO's licensing professionals had a broad range of technical backgrounds with which to handle the spectrum of technologies disclosed by the universities, each bringing with them a network of industrial contacts from their prior history (Annual Report, 1988). TULCO began marketing and licensing activities upon the formal submission of the invention disclosure by a university representative. A representative from TULCO's licensing staff would hold face-to-face meetings with the inventors to build rapport, become familiar with the technology, and craft summaries for marketing. These meetings identified any constraints under which TULCO would have to operate, (i.e. commitments to research sponsors, or public disclosures). Close relationships developed with the campus liaisons from each of the three universities, with TULCO functioning as an extension of the university's offices. Direct personal contact with university liaisons, inventors, and industry representatives expanded TULCO's reach and industry network. TULCO staff could negotiate license terms within the constraints dictated by the university, obtaining consent for any deviation. Special attention was given to companies located in North Carolina, leveraging existing state resources such as the North Carolina Small Business Technology Development Center (SBTDC) and the North Carolina Biotechnology Center (NCBC) in identifying companies interested in developing new technologies (Annual Report, 1988).

[19]Formal operations of the consortium began January 1988, and all data, reports and information obtained on TULCO's operations are from fiscal years 1988 through 1995, fiscal years running July 1 through June 30.

TULCO's licensing staff's time and efforts were divided across several activities: working with the invention disclosures, expanding industry networks, and providing advisory services. Significant time (about 50%) was spent working with university administrators, meeting with faculty inventors, providing educational seminars, and learning the research capabilities of each institution. TULCO staff members attended university patent committee meetings in an advisory capacity to help enhance the entrepreneurial culture and faculty acceptance of technology licensing. Campus visits helped to educate the university researchers on TULCO's objectives in licensing research based inventions, and helped to uncover additional potentially licensable inventions.[20] TULCO staff members also attended university patent committee meetings in an advisory capacity to learn about inventions being considered for patentability, increase awareness of TULCO's services, and enhance faculty acceptance of technology licensing. The licensing staff remained active in professional organizations including the Association for University Technology Managers (AUTM) and the Licensing Executive Society (LES), providing access to industry networks.

Initial reactions to TULCO's establishment were favorable by all parties. Following the first year of operations, the universities were unanimous in acknowledging TULCO's capabilities and resources had increased licensing inventions from their campuses, and had helped to expand the reach of industrial interactions. The feasibility to engage with this level and array of expertise in technology transfer functions on a campus-by-campus basis would not have been possible without the creation of the consortium.[21] Into the second year of formal operations, the inventions submitted for licensing continued to be primarily from biomedical fields (reflecting the relative research bases of the participating institutions). Licensing personnel attempted to contact the university inventors for their active submissions at least once a month, even as activity levels increased. By the third year,

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[20]Discussed in several of the interview sessions, with both licensing staff and faculty inventors; conversations with TULCO's licensing personnel helped inventors consider other potentially patentable inventions for submission.

[21]This was a common theme reiterated throughout interviews with each university representative.

biomedical technologies continued to dominate invention disclosures, expanding to include biological sciences, engineering, materials and instrumentation, and computer science (Annual Report, 1990). Some institutional, cultural, and organizational, differences surfaced during their third year of operations, in addition to differing expectations among the three universities.[22] These issues contributed to the organization's eventual demise, and are explored further. TULCO staff members adapted procedures and worked with each university to address the unique needs of each campus.

TULCO continued to establish relationships with industries in RTP and across the nation. They achieved widespread recognition, increasing international licensing. During the fourth year, negotiations were being conducted with companies based in England, France, Germany, Italy, Japan, and Sweden (Annual Report, 1991). Developing a personal business relationship with industry contacts contributed to TULCO's international expansion of their industry network. Over 600 national and international companies had been contacted in licensing efforts by this fourth year, and TULCO's international network was one of their most valuable assets. In 1991, each of the universities reported record licensing activities, acknowledging TULCO's significant contribution (Board minutes, 9-1991).

Continued efforts were made by TULCO's staff to focus on NC companies to assist with business growth across the state, attending university patent committee meetings, expanding outreach efforts and working with regional venture capital groups. In its fifth year of operations, TULCO continued to experience expanded demands upon its time and resources, with increased invention disclosures and continued personal contacts with inventors and over 700 businesses. This continued expansion caused stress on TULCO's time and resources, creating bottlenecks, and fueling discontent within the universities where they felt their needs were not being properly addressed.

[22]Noted in Annual Reports and several Board meeting minutes, 1990 and 1991

Gradual Disbanding of TULCO

Experiencing some levels of success and frustrations from its initial five years, transition was inevitable for the consortium. Duke made it clear they were pulling all licensing activities in-house by the end of calendar year 1992, reorganizing its technology transfer efforts. The initial campus liaison to TULCO had left Duke, changing the dynamic of the relationship between their technology licensing operation and the consortium. Personnel and other changes taking place at Duke's medical school in the early 1990's and their desire to find alternate licensing arrangements for inventions from specific technology areas contributed to this decision. The successes from TULCO's licensing efforts helped Duke realize that an internal full service technology licensing office was needed to effectively support their faculty inventors.

During the sixth year of formal operations (1992-1993), the original grant from TUCASI was fully expended, Duke had formally left the consortium to pursue commercialization strategies separately, and TULCO experienced several changes in licensing and administrative personnel; contributing to the changing dynamics between the universities and the consortium. A second proposal to TUCASI for funding years six through ten had been developed and submitted, but was withdrawn once it became apparent that Duke would no longer be participating (TULCO Funding Proposal, 1991). TUCASI's mandate was to support joint efforts among all three triangle universities, so funding was not available without Duke's involvement. The two remaining universities, UNC and NCSU, continued TULCO's operations, and regrouped with an agreement between them (NCSU and UNC Agreement, 1994). Duke contracted separately with TULCO during 1993-1995 for licensing support in exchange for their continued maintenance of TULCO's finances and employment contracts (TULCO and Duke Contracts, 1993-1995).

While disclosures from Duke fell off after their exit, submissions continued to increase from the other two universities, continuing to exert demands on TULCO's time and efforts. The licensing staff remained at three individuals after some personnel changes, despite increased disclosure submissions and a growing active case load stretching the limits of available resources. No plans were

made to increase personnel capacity, as TULCO was constrained by the allocated office space provided by RTI.

This more limited arrangement between UNC and NCSU terminated in 1995 as NCSU eventually followed Duke, expanding internal capacity and pulling all licensing activities in house. NCSU cited several reasons for leaving TULCO, including lack in growth of adequate resources at TULCO (space, personnel, expertise) needed for their rapidly expanding caseload (both in size and complexity), growing information management needs, pressure for new business development from the university, and an increased need for ongoing maintenance of relationships with their licensees. NCSU's industry relationships had expanded into areas such as computer science and information management, with no corresponding licensing capabilities added to TULCO's services. NCSU also expressed a need to expand their networks with venture capital firms, business development professionals, professional organizations, government agencies, economic development organizations, and other service providers, and a desire to improve efficiency and effectiveness in the early stage evaluation process (NCSU Challenges and Opportunities, 1995). With NCSU's departure from the consortium, UNC had to increase their internal technology licensing capacity as well, and hired their first technology transfer Director in September of 1995. This new director worked with TULCO to finalize licensing projects, eventually making all licensing activities internal, allowing UNC to address their expanding entrepreneurial and commercialization needs of their faculty.

Some of TULCO's intangible assets were captured by the triangle universities as TULCO disbanded. Two of the three (the TULCO Director retired) licensing personnel were brought into technology licensing offices within Duke and NCSU, retaining some resources, knowledge, and industry network cultivated during TULCO's operations. These intangible assets: the people, their experience, tacit knowledge, and personal networks developed during their TULCO experience were a boon to the institutions able to retain them, and helped with the smooth transfer of licensing activities. During the transfer of licensing activities back to the university, active projects early in the

commercialization process were pulled back into the universities. TULCO's agents completed those close to finalization of an agreement.

Cultural and Resource Constraints Contributing to Dissolution

The differing cultures of each institution, and the growing resource constraints at TULCO had a large contribution towards the eventual disbandment of the consortium. Differences in institutional culture, organizational processes, and expectations of TULCO surfaced during their third year of operations. The unique characteristics and circumstances of each university required some adaptability in TULCO's licensing approaches, while retaining the basic mission of the consortium to commercialize the inventions disclosed from the universities. Cultural and historical differences, adaptability in license negotiations and terms, differences between public vs. private institutions, and differences in policy environments were all issues that had to be accounted for in the operations of the consortium. The board and staff members of TULCO recognized these differences among the three universities and tried to work with each to ensure the special needs of each were appropriately addressed.

At the time of TULCO's formation, Duke was (and continues to be) a prestigious private research university, with strong research activities and industry partnerships in their medical school, NCSU a strong public agricultural land grant university, with engaged faculty in agricultural, engineering, and information management research, and UNC a prestigious public research university, with research strengths in chemistry, pharmacy, and a burgeoning computer science department. Subsequently, each university had very different cultural environments and histories, creating instances where TULCO's licensing staff had to adapt their licensing strategies to meet the differing needs of the universities.

NCSU's documented struggles with meeting the growing technology licensing and commercialization needs for their expanding research and industry research partnerships are additional indicators of a lack of adequate expansion in licensing personnel and other services within

TULCO to keep up with the rapidly expanding marketing and commercialization needs of each of the triangle universities. The increasing research diversity and invention disclosure activity levels, without additional corresponding resources allocated to TULCO's operations diminished their ability to provide unique marketing, licensing and commercialization efforts for the universities. Physical space constraints were a key barrier to expanding resources at the time. The consortium acted as a catalyst, transforming the internal infrastructures of each research university to meet a growing need in support of technology licensing and commercialization.

Methodology

In light of the fact that regional consortia are being advocated in national level policy discussions, TULCO is analyzed here as a case study of one regional licensing consortium effective in helping institutions increase their technology licensing effectiveness. This collaborative entity is studied from its inception to conclusion, providing historical context of its operations and effectiveness in licensing the academic inventions from the three universities. This case study project was designed to answer the following questions regarding this early technology licensing consortium: How and why did the three triangle universities decide to collaborate in a technology licensing consortia? How effective was TULCO in effecting the entrepreneurial culture within the universities and expanding the commercialization capacity in the Research Triangle universities? And finally, why was TULCO disbanded?

This case study utilized qualitative analysis through semi-structured interviews and archival document review as sources of evidence to study this technology licensing consortium in the RTP. Interviews and conversations were held with eight individuals who had worked directly with TULCO in various capacities, employees of the consortium, inventors, board members, and the three university representatives or liaisons to TULCO. Interviews followed an open ended discussion guide (Appendix A), to encourage interviewees to talk about their experience with TULCO, providing insightful information on TULCO's operations and explanations of its eventual demise. Interviews

led to the identification of archived documents; TULCO's Annual Reports, board meeting minutes, and other materials held by Duke's legal counsel's office. Access to those materials was graciously granted by that office, and allowed a fuller analysis of the yearly ongoing licensing activities of TULCO. Information from TULCO's annual reports on disclosures received, confidentiality agreements, license negotiations (initiated and finalized), and active, open case files at the end of each fiscal year was pulled from those annual reports to allow quantifiable analysis of yearly activities. Data on the triangle universities patenting activities were obtained from the USPTO for a 24 year period, the 8 years prior to TUCLO's formation, 8 years during, and 8 years post operations. Data on NC patents issued (from each year in which the patent applications were filed during TULCO's operations) was provided by Dr. Maryann Feldman who received cleaned and verified USPTO patent data for North Carolina from Dr. Deborah Strumsky at UNC Charlotte. This patent data is evaluated to understand TULCO's impact upon the universities propensity to engage in intellectual property protection during this time frame. Licensing activity and royalty income for each of the universities was obtained from the Association of University Technology Manager's Statistics Access for Tech Transfer (STATT)[23] database, available from 1991 onward.

These multiple sources of data and information on the operations of TULCO from archived annual reports, board meeting minutes and other records, interviews, and patenting data of the three universities provide insight into the daily operations of the licensing consortium. Interview discussions are validated by information contained in the archived documents (board meeting minutes, annual reports, and correspondence), further validated by the increased patenting activity of the three institutions as evidenced from the USPTO. AUTM data post TULCO for the three Research Triangle universities indicate the continued growth of technology licensing activities at the three universities after the licensing consortium was disbanded. This quantitative data combined with insights obtained from interviews allowed a chronological time series analysis of TULCO's activities

[23]Statistics Access for Tech Transfer (STATT): a searchable database of academic licensing data collected by AUTM from participating research universities and other research institutions.

over its eight year time span, and evaluation of TULCO's impact upon entrepreneurial cultures and technology licensing activities at each of the universities.

Analysis of TULCO Technology Transfer Activities

Records from TULCO's operations and communication between Board members indicate a significant increase in licensing of the three universities' inventions during the 8 years of TULCO's operations. Information gathered in interview sessions indicated TULCO may also have had an additional impact upon patenting activity at its outset, as faculty inventors were encouraged to think about the applied outcome of their research, and disclose other research results not previously considered. Initial faculty interviews with TULCO's licensing professionals often generated other invention disclosures from active research faculty[24]. Information was collected from TULCO's annual reports on the numbers of disclosures received, confidentiality agreements started and finalized, license negotiations started and finalized, and active, open case files at the end of each fiscal year (table 3.1). Some records are missing from this set of archived materials; however enough information could be obtained to provide a full picture of TULCO's activities and the constraints under which they operated. Analysis of these documents helped identify TULCO's success and some missteps of this licensing consortium. Interviews supplemented and supported the data.

[24]This was another recurring theme across interview discussions with TULCO stakeholders.

Table 3.1 TULCO Activities

Year	Invention Disclosures	CDA Started	CDA Signed	Licenses Started	Licenses Completed	Active Files	Total Patents Issued[25]
1988*	98	76	48	41	11	81	37
1989	111	133	105	63	20	131	25
1990	142	112	88	84	41	168	34
1991	120	101	85	70	42	205	40
1992‡	146	107	88	63	34	216	91
1993	114	97	67	46	52	236	77
1994	131	132	115	42	35	255	117
1995†	47	35	30	11	21	297	151
Totals	909	793	626	420	256		572

* 6 months of official operations, activities started with hire of Exec Director in 1987
‡ Duke left consortium at end of 1992
† Data only available for 1st quarter of fiscal year.

Trends in Disclosures and Active Projects

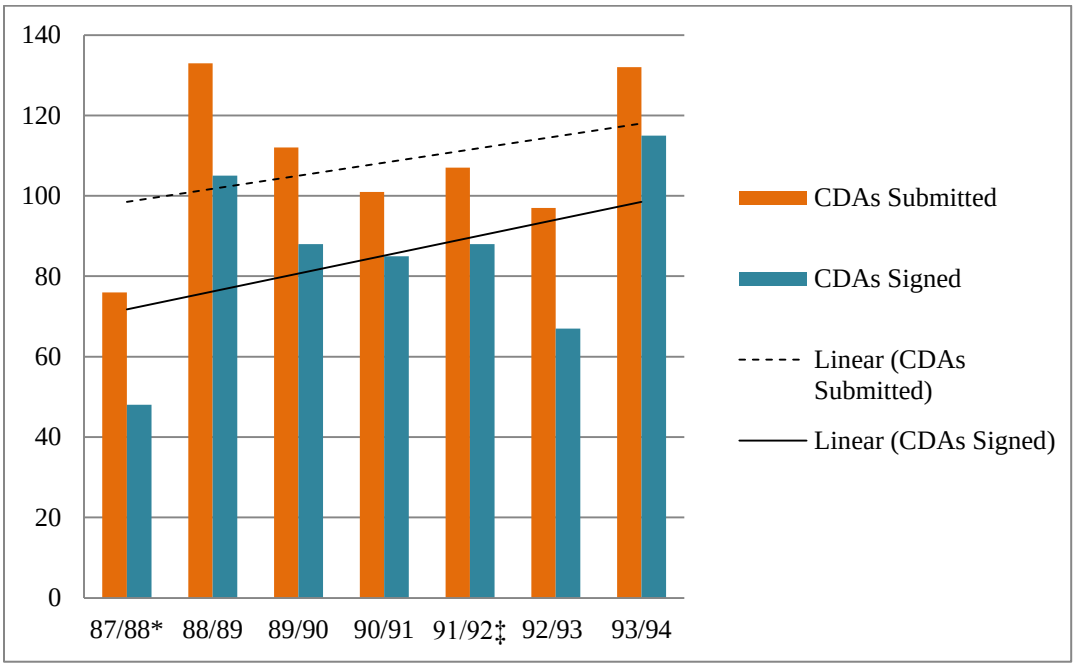
Disclosure submissions were not distinguished by university each year in TULCO's annual reports, but show growth in the initial three years as the consortium developed its internal capabilities and infrastructure. Submissions grew by 45% during the first three years as the consortium got underway, indicating a pent up supply of inventions developed from research. The submission rate leveled off after this initial period, indicative of a point of equilibrium being reached. Over its first seven years of operations, TULCO averaged 123 submissions per year, quite a number considering its licensing staff of three people (TULCO Annual Report, 1994). While the disclosure submissions from the triangle universities leveled off somewhat after the first three years, the active open case load for marketing and licensing efforts continued to increase over the duration of TULCO's operations. As disclosure submissions continued at a steady rate with no corresponding increase in personnel, space or other resources allocated to the operations, TULCO's capacity limitations became apparent.

[25]These numbers are total for all three triangle universities, and are those patents issued from the patent application filings in each year of TULCO's operations.

Confidentiality Disclosure Agreements

Confidentiality Disclosure Agreements (CDAs) are submitted in advance of discussing any technical specifications of inventions with prospective licensees. As such, these agreements to keep the underlying functions and mechanisms of the innovations confidential could be viewed as leading indicators of TULCO's subsequent licensing negotiations. Licensing negotiations with an industry representative would not proceed without such an agreement in place. A total of 793 of these CDAs were submitted to industry contracts who expressed interest in learning more about the academic inventions during the eight years of TULCO's operations, 626 of those were signed (79%). These finalized CDAs demonstrate TULCO's licensing staff's effectiveness in outreach efforts to potential licensing partners and in building a strong international network of contacts with industry. Figure 3.1 below includes a trend line which indicates the positive trends for both submitted and completed confidentiality discussions with industry.

Figure 3.1, TULCO Confidentiality Agreements, Submitted and Signed



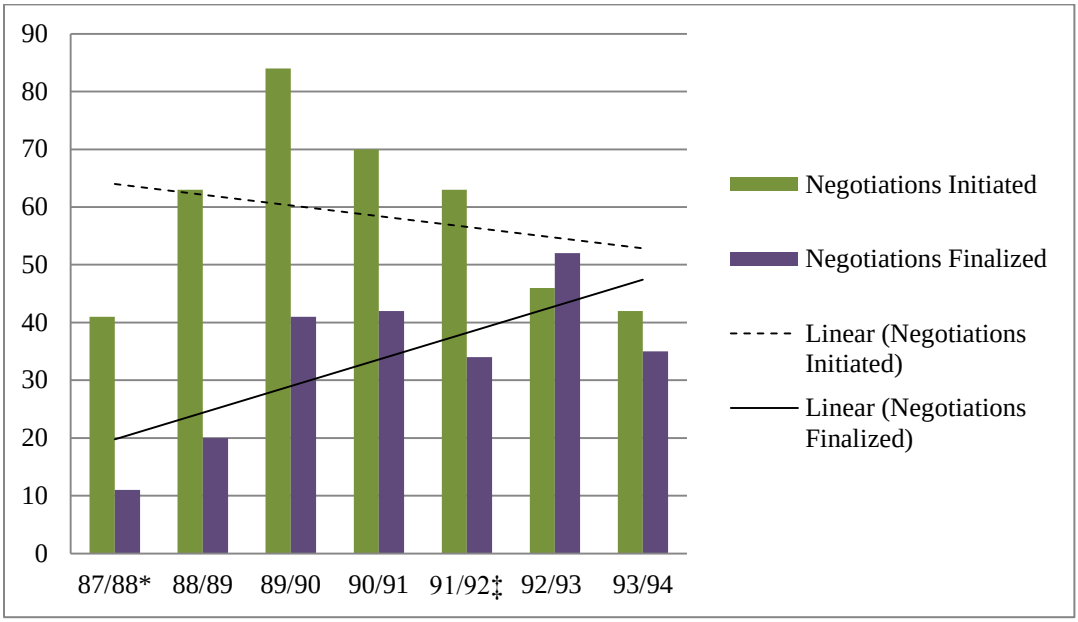
* 6 months of official operations, activities started with hire of Exec Director in 1987
‡ Duke left consortium at end of 1992

Licensing Negotiations

Over the eight years of TULCO's operations, 420 license agreements were initiated with industry partners, with 256 of those being successfully finalized; about 61% (table 3.1). During the first three years of TULCO's operations, the licensing professionals dealt with the pent up supply and demand for academic technology licensing in the triangle region. The number of licensing discussions started with potential industry partners grew by 105% during that brief time frame, with the number of those finalized increasing from 11 the first year to 41 in the third. After that initial growth, the number of negotiations initiated with companies declined each subsequent year, potentially reaching a point of diminishing returns upon the resources of the licensing staff. Finalized licenses each year continued at a steady rate, dropping with some uncertainty in 1992, increasing again in 1993, TULCO's licensing professionals completed an average of 40 licenses per year with industry.

Figure 3.2 below represents the initiated and completed license negotiations from 1988 through 1994 (complete data was not available for 1995). Linear trend lines show the relative decline in negotiations initiated over TULCO's time span, and the relative increase in license negotiations finalized with industry licensees. The steady increasing rate of finalized licenses each year is indicative of the licensing staff's continued efforts and success in getting research based inventions into the commercial pipeline. This trend is supported by conversations from several interviews, licensing staff were committed to building and maintaining relationships with industry contacts, and those relationships in turn facilitated successful licensing negotiations and opened doors to other contacts; expanding TULCO's reach and industry network.

Figure 3.2, TULCO Licensing Negotiations, Initiated and Finalized



* 6 months of official operations, activities started with hire of Exec Director in 1987
‡ Duke left consortium at end of 1992

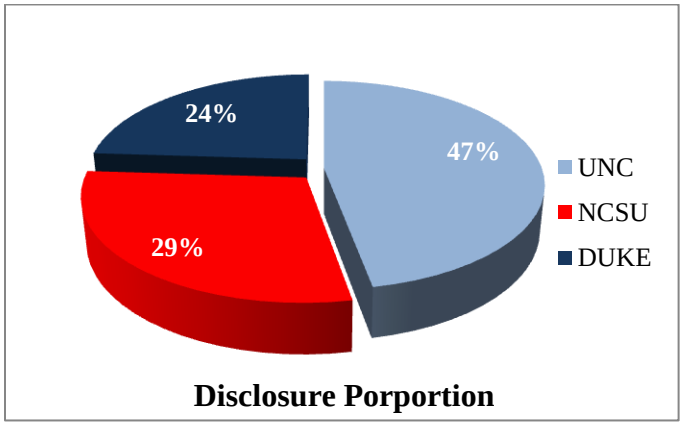
While it would have been beneficial to compare this activity to similarly funded research institutions across the US, the appropriate data are not available. AUTM data are only available after 1991 so a comparison to similar institutions that operated individually is not possible. Still there is empirical evidence to demonstrate that technology transfer activity of the three triangle universities increased under TULCO.

The active open caseload for marketing and licensing efforts continued to increase over the duration of TULCO's operations, growing to almost 300 unlicensed invention disclosures in 1995 (table 3.1). This increasing level of open cases over TULCO's operations reflect the maturing of the portfolio and the long-lead time (from initial disclosure to a successful license) typically experienced for early stage academic inventions. As disclosure submissions continued at a steady rate with no corresponding increase in personnel, space, or other resources allocated to the operations to address the increasing caseload, TULCO's capacity limitations became apparent.

Submission Proportion for each University

Duke and NCSU utilized the consortium as an extension of their existing technology licensing operations, retaining disclosures they had internal capacity to handle, sending those inventions that could benefit from their expanded expertise and network, while TULCO functioned as UNC's sole licensing operation.[26] Yearly disclosure submission data was not available for each university from TULCO's Annual Reports, as the consortium reported all disclosures together. However, minutes from Board meetings provided data points indicating the relative invention disclosure submission percentages from each of the universities (Board minutes 9-1994). By Fall of 1994, the triangle universities were reassessing their technology licensing needs and capacity, UNC was the primary beneficiary of TULCO's services, as their invention disclosures comprised almost half (47%) of all total disclosures received by the consortium, with Duke submitting 24%, and NCSU 29%. These latter numbers also reflected Duke's withdrawal in 1992 (figure 3.3).

Figure 3.3, Disclosure Proportion by University 1988-1994



UNC's utilization of TULCO's operations for all invention disclosures indicates their lack of any internal marketing or licensing skills. This data may also provide some indication why Duke and NCSU felt they were not receiving a fair share of the services provided by TULCO's operations to

[26]This was confirmed by each of the university representatives interviewed.

continue their participation in the consortium, justifying their internal capacity expansion to meet the growing demand from their research faculty.

Patenting Trends

To evaluate TULCO's impact upon the inventive capacity of each institution, data was also obtained on issued patents that were applied for during the eight years prior to TULCO's operations (1980-1987), the eight years in which TULCO was in operation (1988-1995), and the eight years following its demise (1996-2003) (See figures 3.4-3.6 in Appendix B, *Issued Patents*). Prior to TULCO's formation, applications for patents that were subsequently issued during 1980-1987 were nonexistent, or in the single digits. Patenting increased slightly at each university in the mid 1980's, driven by the passage of the Bayh-Dole Act; following a national trend of increased patenting activity across US research universities (Mowery, Nelson, Sampat, & Ziedonis, 2001). During TULCO's eight year time frame, 1988-1995, the patenting activity at each of the three universities saw significant growth (table 3.2). Issued patents from those filed for the three universities during TULCO's eight years increased dramatically as seen in figure 3.5, reflecting a confluence of several initiatives to increase the commercial potential of academic inventions, nationally and within the triangle region. Table 3.2 includes reported royalty income to AUTM after 1991, Duke's royalty income reporting starting in 1993.

Table 3.2, Issued Patents, and reported Royalties, 1988-1995

Year*	Duke Issued Pat	Duke Royalty $	UNC Issued Pat	UNC Royalty $	NCSU Issued Pat	NCSU Royalty $
1988	13		10		14	
1989	10		6		9	
1990	6		11		17	
1991	10		11	393	19	818
1992	36		15	414	40	1,101
1993	27	641	17	575	33	1,543
1994	52	1,556	30	886	35	1,632
1995	48	1,790	68	983	35	1,823

*Patents issued from application year, $ amounts in thousands

Technology protection and licensing functions had become more fully developed at each of the universities by the mid-1990s, stimulated by the technology licensing consortium and the growing entrepreneurial culture at each university. Data available on issued patents and royalty income for each university for the subsequent 8 years (table 3.3) after TULCO's demise indicates the expanding entrepreneurial culture and internal resource capability growth at each institution to meet expanding needs of the research faculty.

Table 3.3, Issued Patents, and reported Royalties, 1995-2003

Year*	Duke Issued Pat	Duke Royalty $	UNC Issued Pat	UNC Royalty $	NCSU Issued Pat	NCSU Royalty $
1996	36		26	1,389	37	
1997	32	1,520	52	1,684	25	3,165
1998	51	1,319	30	1,890	30	4,281
1999	53	1,600	36	1,706	37	7,761
2000	38	4,329	48	953	49	2,558
2001	48	5,719	36	1,227	53	3,545
2002	48	4,977	43	1,284	53	3,720
2003	43	2,794	33	3,863	45	4,603

*Patents issued from application year, $ amounts in thousands

With commercialization of academic inventions an expressly stated national policy goal, infrastructure and incentives were aligning to create an entrepreneurial culture at each of the universities. TULCO was instrumental in meeting that need for the triangle research universities, expanding knowledge and helping expand acceptance of entrepreneurial and innovative activities across each campus. Campus visits and participation in seminars helped faculty inventors think about the potential applied outcomes of their research, and invention disclosures were submitted that might not have without TULCO's involvement.

The existence of TULCO allowed the three research universities surrounding NC's Research Triangle Park to share resources, allowing more effective and efficient transfer of the academic inventions to industry than would have been accomplished had each campus acted individually. The presence of this early licensing consortium provided a short-term mechanism to address a growing need when technology licensing infrastructure and capabilities within each campus were in short

supply. The discussion and analysis of trends in the data on invention disclosures, confidentiality and license agreements, patents issued, and royalty income to the universities during TULCO's timeframe suggest that the formation of this licensing consortium among the three triangle universities had a significant impact upon the internal culture of entrepreneurship at each of the institutions involved. Each of these technology transfer related activities grew substantially during TULCO's timeframe. Acceptance of technology licensing and commercialization with the research faculty at each of the institutions grew in response to TULCO's activities and engagement, enabling the successful licensing of 256 inventions to industry from the three universities.

Evidence from Interviews

Interviews were held with eight individuals who had worked with the licensing consortium in various capacities: the three university representatives who worked directly with the consortium during its initial operations, members of TULCO's licensing staff, a board member, and a faculty member who had worked with the consortium both as an inventor and through the university's internal patent committee. Perspectives from these interviews provided some supplementary information unavailable from the annual reports and board meeting minutes, highlighting differences in culture, research functions, flexibility, and expectations of TULCO at each of the universities in addition to the constraints faced by the licensing staff. Identities of these individuals remain confidential; titles are utilized when permission was given to do so.

Cultural and Institutional Differences

The differences in history and culture at each of the universities became clearer throughout the conversations with the individuals involved with TULCO. Recognition of these institutional differences was expressed in TULCO's third Annual Report (1990). All three were high research-intensive universities, with research funding levels at about $120-150 million dollars (NSF Webcasper). Confirmed in the interviews, Duke University, already engaged in industry research, had

more experience and internal cultural acceptance of entrepreneurial activities, and as a result, had high expectations from TULCO's licensing staff in engaging industry to license their inventions. UNC, as a flagship institution of the North Carolina University System, had high levels of research activities, but a non-existent internal entrepreneurial culture, and no internal experience or capabilities for technology marketing and licensing. UNC's lack of cultural acceptance towards entrepreneurship and technology commercialization required significant engagement by TULCO's licensing staff for educational seminars and informational sessions. Finally, NCSU, as a land grant university and another flagship of the North Carolina University System, had strong programs in engineering, textiles and agriculture, and some experience with industry partnerships, resulting in more cultural acceptance for entrepreneurial activities on their campus.

Each university filled a different niche in their research environments and capabilities, shaped by their cultural environment, funding, and faculty research; providing limited opportunities for bundling inventions among them for commercialization. These institutional cultural and historical differences, differing expectations and internal directions of burgeoning research areas led each of the triangle universities to pull all technology licensing and commercialization activities in-house to meet the expanding faculty needs as internal cultural acceptance of entrepreneurial activities grew.

Existing Internal Capacity

Internal capacity at the universities for technology transfer at the time was reactive, responding to pressures from engaged faculty, and capacity growth was needed. NCSU was hiring a new director of technology transfer in 1984 to increase their internal technology licensing capacity beyond the university counsel's office when the consortium was being considered, and Duke was hiring a director in 1986 to take over their technology licensing office when TULCO was formalized. Duke and NCSU had higher levels of faculty acceptance toward entrepreneurial activities. There was some concern expressed of overlapping functionality with the new director hired at NCSU while TULCO's formation. The consortium was recognized however, as helping to expand the availability

of commercialization services available at NCSU. UNC utilized external resources for all marketing and licensing efforts for the few invention disclosures they received prior to TULCO's formation. Once TULCO was established, UNC utilized their services for all marketing and licensing activities, creating a sense that the public flagship university used TULCO's resources disproportionately.

Working with TULCO

Each of the university representatives to the consortium noted their respective universities benefitted from TULCO's presence in helping the universities gain capacity in marketing and licensing their inventions, and in educating faculty members. An early member of TULCO's licensing staff expressed great pleasure with the initial operations of TULCO, and felt the consortium kick-started marketing and licensing activities at UNC, and enhanced existing activities at Duke and NCSU.

During discussion and review of patenting data for each of the universities, one interviewee suggested that the combined effect of TULCO's impact upon the entrepreneurial culture at each university, the encouragement for faculty to disclose inventions, and the fact that the marketing and licensing functions were being paid for by an external source, all strongly influenced the receptiveness and willingness of the research faculty at each university to bring research results forward for potential patenting and commercialization. With limited resources on their individual campuses, the university representatives all noted that TULCO's services enhanced and helped expand their technology commercialization capacity beyond what they would have been able to do individually. While each of these university representatives indicated TULCO's enhancement of their technology licensing activities, there were some indications during these interviews that the universities received different levels of service from TULCO based upon their needs. Towards the end of the consortium's operations, when internal commercialization capabilities at the universities had developed sufficiently to meet the growing demands of their research faculty, it made sense at

each university to bring the provision of marketing and licensing services in-house to meet faculty inventors needs more effectively and efficiently.

Concerns

These discussions with individuals who had worked with TULCO confirmed the expanding submission rate and active projects with no corresponding expansion in available resources during the last three years of operations had a detrimental impact upon the ability of TULCO to meet the established expectations at each university. Staff changes within the universities and TULCO also changed existing relationship dynamics. TULCO's operations were run from their RTI offices in RTP, and while fairly close to each of the triangle universities, TULCO's licensing staff spent considerable time and effort to interact with the research faculty in face-to-face meetings, particularly as demands grew for TULCO's licensing and commercialization services. The increased volume of invention disclosures and technology licensing activities and the inability of TULCO to meet the expanding needs of the three universities warranted either an enhanced investment in the licensing consortium, or an expansion of the existing internal technology licensing operations within each of the triangle universities, particularly as faculty embraced the growing entrepreneurial culture. Communication breakdowns at the end of TULCO's operations caused some friction. One director of an internal technology licensing function felt TULCO's management had not fully understood they were being replaced by the growing internal capabilities within each university.

Discussion

The history of TULCO presented above provides some background on how and why these three triangle universities decided to collaborate through a technology licensing consortium. Pressures to provide access to the results of federally funded academic inventions were increasing from regional legislators, and entrepreneurial faculty members at each university were beginning to tax the existing limited internal capabilities at each institution. Institutional responses to the increased pressures from

entrepreneurial faculty were more reactive than proactive, and there were limited internal capabilities for technology licensing. The formation of the consortium allowed the three regional institutions to leverage their geographic location and proximity to each other, utilize existing internal capabilities, expand access to marketing resources and subject matter domain skills, and increase each university's network with industry for successful licensing.

As evaluated above, the activities engaged in by TULCO's licensing staff promoted the successful licensing of at least 256 inventions from the three universities, and contacts with regional, national and international industries expanded business networks. Interviews with key stakeholders all suggested early successful licensing efforts would not have happened without TULCO's efforts in expanding industry networks. In response to activities by TULCO licensing staff in engaging with academic researchers on each campus, additional invention disclosures were brought to TULCO for potential licensing. TULCO's efforts in working with research faculty helped to enhance the entrepreneurial culture within the universities, increasing demand and desire for technology commercialization and industry engagement. The commercialization capacity in the Research Triangle universities developed over time as the entrepreneurial culture expanded and technology licensing needs grew. Since TULCO was not able to expand space or add licensing staff or other resources in response to the growing needs and expanding research focus areas of each of the universities, internal licensing capabilities, processes and structures grew at each university in response to the increased needs of their research faculty.

Some cultural differences among the three triangle research institutions became apparent a few years into the consortium, as well as differing expectations of the consortium from each university. The consortium attempted to respond to the individual expectations of each university, but was unable to expand its own capacity to meet the rapidly expanding research areas and growing technology commercialization needs. As each of the universities expanded internal capacity to meet growing needs of entrepreneurial faculty members, the need for TULCO's services began to diminish. NCSU and Duke University each developed specific processes in support of their individual needs to

more effectively support their research faculty and growing institutional needs. As each of these two universities pulled technology commercialization activities in house, TULCO was eventually disbanded and UNC subsequently formalized their technology internal commercialization efforts, staffing a full office in 1995.

TULCO provided an expansion of commercialization functionality in the Research Triangle as each university was constrained by its history and culture, funding limitations, lack of incentives, and slowness to adapt to the increasing need for technology commercialization, characteristics identified in previous studies as limitations to success in commercializing academic inventions (O'Shea, et al., 2005; Link & Scott, 2005; Renault, 2006). TULCO was initially successful in addressing a growing regional need to expand technology licensing and commercialization of the academic inventions from the three triangle universities. The licensing consortium was effective in expanding the entrepreneurial culture across each of the three institutions, increasing acceptance of research faculty for technology commercialization efforts. These three research universities were able to have an impact throughout the regional economic environment through this technology licensing consortium and the successful licensing of 256 university inventions to regional, national and international industry partners. The growing receptiveness to entrepreneurial activities on each campus increased each institution's needs beyond TULCO's capabilities to meet, which in turn enabled each institution to expand their internal capabilities to meet the growing needs of research faculty.

Recommendations

Recommendations for technology licensing consortia have been put forward by the Kauffman Foundation, and have appeared in federal bills introduced to Congress, including the America Innovates Act of 2012 (H. R. 4720), and Startup Act 2.0 (S. 3127), both introduced to the 112th congress. While these federal bills stalled in committee and were not successful in becoming law, discussions are still maintained at the national level on accelerating technology transfer from federally

funded research, with the reintroduction of the Startup Act 3.0 (H.R. 714 and S. 310) introduced February 2013, and continuing discussions regarding technology licensing efforts among research universities and joint research institutions to facilitate technology transfer from research universities across the US.[27]

Each individual interviewed for this paper agreed that forming a technology licensing consortium helped the triangle universities move the academic inventions towards commercialization more efficiently and effectively, established a broader domain expertise in licensing staff, helped build infrastructure and capacity, and increased acceptance of an entrepreneurial culture with the faculty at the universities involved. Some recommend technology-licensing consortia as an alternative technology commercialization mechanism for smaller research universities. Their recommendations contribute to this section.

A regional licensing consortium may be considered as a potential blueprint by smaller universities, or state systems with smaller schools that might benefit from combined resource capabilities. The TULCO model may be most effective for regional research universities with limited internal licensing capacity and funding for technology licensing. By engaging in a consortium or partnership, universities may broaden their domain in subject matter expertise and specialization of staff by leveraging each other's knowledge and experience in technology licensing with minimal impact upon budgets. As with TULCO, having an organization function as a single point of contact for multiple organizations may produce efficiencies for prospective industry partners; perhaps with them being more willing to take a look at academic inventions through a single licensing portal.

Universities contemplating such a consortium would benefit from similar research goals, and similar initial attitudes toward faculty entrepreneurial and engagement activities. Complementary and overlapping research portfolios can build advantage. Institutional histories, regulatory environments and social norms and cultures of the universities joining in such a consortium need to be compatible

[27]Department of Commerce Technology Transfer Plan (NIST) http://www.nist.gov/tpo/publications/upload/DOC-Tech-Transfer-Plan.pdf, published September 2012.

or complementary to each other to facilitate growth and change (North, 1990). Outside entities forming a consortium for a group of research universities that are not familiar with their internal cultures will find it harder to be effective.

To be successful, each university involved must be fully committed to partnership in the consortium, with full buy-in by all involved, and with strong internal champions from the leadership of the universities actively supporting the initiative. Faculty researchers must feel supported and incentivized by university leadership in their entrepreneurial initiatives, and to be sure those activities do not detract from career advancement.

The existence of consortium must serve the mission of the participating universities solely, not to perpetuate itself. Metrics, reports, and other public information must be evaluated at the university or institutional level, in order to accurately measure whether the consortium is being effective for the universities involved. Employees must understand the organization is working for the universities and is not an agent on its own. Staff members of any licensing consortia among universities must be closely aligned with the mission and culture of the universities involved in order for the needs of those universities to be understood and met.

High-touch or high engagement is important in technology licensing, and successful partnerships come with the development of personal relationships. The relationships established between TULCO staff and the campus liaisons facilitated the technology commercialization processes for all involved. Physical proximity during the time of TULCO's operations was considered extremely important, as licensing and technology transfer is considered a 'contact sport' requiring a lot of personal interaction, a lot of face-to-face, handshakes, and being together. Closeness in industry-university partnerships develops over time, those relationships strengthened through shared norms, attitudes, values and expectations (Asheim & Coenen, 2006). Technology licensing requires strong engagement with faculty inventors and industry networks alike to help build trust and rapport that enables successful commercialization.

Meaningful incentives must be in place for the licensing staff of a consortium to promote all inventions. Employment compensation cannot be tied to royalty income for technology licensing efforts, as focus will turn to those inventions with the highest revenue generating potential, leaving orphans behind. If the goal is to move inventions forward to the benefit of the public rather than generate revenue, an appropriate compensation plan can help ensure all disclosed inventions are given equal treatment. TULCO's model was considered a successful one in this area–their licensing staff members received no percentage of licensing income, and were judged on metrics beyond any income received from their efforts.

A strategic focus upon creating technology-licensing consortia between research universities can facilitate capacity building and long-term successes in commercialization efforts if it is appropriately resourced. The consortium's long-term outcome must be kept firmly in mind, to fully understand where funding will come from over time, and to know what to do when there is no longer a need for a collaborative organization. A good exit strategy will have an orderly plan for capturing all of the tangible or intangible assets once the consortium is no longer needed. This follows recommendations from previous studies; technology commercialization and licensing efforts need to be driven by long-term goals, provided with sufficient resources (human and financial) to achieve these objectives, and monitored over time for performance to determine how resources can be realigned (Siegel & Phan, 2005).

Conclusion

This analysis of an early stage regional licensing consortium provides valuable insights and an opportunity to evaluate its potential applicability for a regional model among US research universities. Economies of scale and scope were realized as the consortium hired licensing professionals with a variety of backgrounds that reflected the diversity of research at the universities, enabling them to effectively engage with inventors and industry contacts in each of the research areas. The net result was an increased disclosure submission rate at each campus, increased patent

applications (and subsequent issued patents), successful licensing of languishing university based inventions, and an expanded industry network. The consortium helped the universities realize efficiencies in technology licensing through deeper domain expertise and economies of scale in sharing three licensing professionals among them.

This is a single case study analysis of an early stage regional licensing consortium in NC's RTP, and therefore there are limitations in its applicability. However, this study can provide guidance for those considering the development of technology licensing consortia between regional research universities. This model may be considered as a potential blueprint by smaller universities, or state systems with smaller schools that cannot fund internal technology licensing functions. With the knowledge and recommendations gathered from this single case-study, technology licensing consortia being considered or initiated by regional research universities have knowledge of TULCO's successes that could be replicated and potential pitfalls to be avoided in their approach to a similar collaboration. If this model is adopted by other research universities across the US and internationally, continued evaluation of new consortia can provide further information for analysis of how this model may work to address current technology marketing and commercialization needs for inventions created from the academic environment.

Chapter 4. US University Organizational Characteristics and Technology Transfer Performance

Introduction

Moving academic innovations into the public sector, the 'technology transfer process' is increasingly considered a source of unencumbered revenues by university administrators and of economic development by regional legislators (Siegel, 2012). Increased expectations for the commercialization of university research outcomes have prompted universities to look for ways to become more entrepreneurial and effective in technology transfer (Bercovitz & Feldman, 2006; Audretsch, 2013). The university's technology licensing office (TLO) is the organizational unit responsible for protecting (via patent, copyright, trademark), marketing, and commercializing innovations with commercial value, a requirement set in place with the passage of the federal Bayh-Dole Act of 1980 (P.L. 96-517). Considerable attention is paid in prior analyses to the growth in university patenting, licensing, revenue generation and startup formation, as well as the many factors and university characteristics that influence the technology transfer process (Siegel, Wright, & Lockett, 2007; Rothaermel, Agung & Jiang, 2007; Bradley, Hayter & Link, 2013). Siegel and others suggest technology licensing offices may not be optimally configured to achieve their goals, with potential barriers including a lack of business and commercialization skills in the TLO (Siegel, Waldman & Link, 2003; Siegel, Veugelers & Wright, 2007; Markman, et al., 2005a; Litan & Cook-Deegan, 2011). Some have noted it would be useful to understand whether disparities in technology transfer outcomes reflect differences in organizational structure, staffing and other resources, or if certain characteristics may be counterproductive (Merrill & Mazza, 2010, p. 43 & 45). This study helps to address these questions.

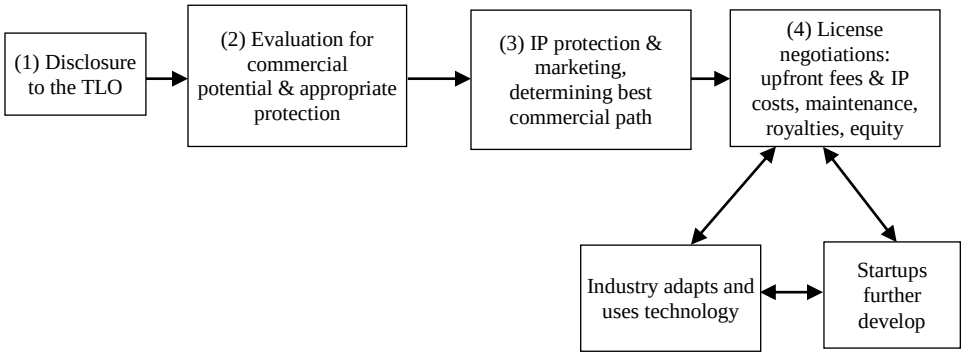
The organizational structures of TLOs can have an impact upon the technology transfer process; several have determined the TLOs financial organization can influence licensing and startup efforts (Markman, et al., 2005a), and use of equity in licensing (Feldman, et al., 2002; Markman, et al., 2005b). The autonomy of the TLO to work with licensees and university startups and to leverage external resources and business networks also has an influence upon a university's success in startup formation (Markman, et al., 2009). The reporting structures of university TLOs (the organizational characteristic evaluated in this study) vary across universities and can include: 1) reporting directly to the chancellor or president of the institution, 2) reporting to an office of research, 3) reporting to an economic development office, or 4) reporting to multiple offices (Feldman & Bercovitz, 2010). We study the influence of organizational reporting characteristics on three commonly reported technology transfer measures: invention disclosures received by the TLO, licenses to industry, and startups formed for the commercialization of university inventions. We find some TLO reporting structures more effective at certain technology transfer outcomes than others. For example, TLOs reporting directly to the university leader or to an economic/business development office may be more effective in university startup formation than TLOs reporting to an office of research. TLOs reporting to multiple functions may be more effective in licensing activities than TLOs reporting directly to the office of research or to an economic/business development office, but less effective at startup formation than TLOs reporting to the institutional leader. Comparisons of each structure to the others are further analyzed below.

Characteristics of the individual charged with running and managing the efforts of the TLO may also have an influence: the last educational degree and job tenure of the TLO directors in the sample are evaluated to determine their influence upon disclosure activity, licenses and startups. We find that different educational backgrounds of TLO directors can influence the technology transfer process and its outcomes, providing support for those who suggest an expansion of commercial expertise in the TLO may have a positive effect (Siegel, et al., 2007, 2008, 2012; O'Shea, et al., 2005; Swamidass, 2013). Specifically, we find TLO directors with an MBA degree to be more effective in

obtaining invention disclosures and working with startups than TLO directors with a PhD, and more effective at licensing activities than TLO directors with a Juris Doctor (JD) degree. Our analysis finds TLO directors with JDs to be less effective in licensing outcomes than all other educational backgrounds, providing some support for Siegel, et al.'s (2003) implication that legal wrangling may reduce university licensing efforts.

The process of academic technology transfer is presented in the subsequent section with a discussion of how organizational and educational characteristics of the university TLO may impact that process. Past studies provide a framework for the predictions for this analysis. The data and methodology are presented, followed by results and discussion of the findings from the quantitative analysis. The specific contribution of this current study and the resulting policy implications are considered in the final section.

Figure 4.1 Internal University Technology Transfer Process



Process of Technology Transfer

The TLO bridges the academic and commercial worlds to move research inventions into public use; this analysis focuses upon the internal mechanisms of the technology transfer process (figure 4.1), and the influence TLO organizational characteristics may have upon that process.[28] A

[28]Many other models exist which demonstrate the complexity and flow of technology transfer (see for example, Swamidass & Valusa, 2009; and Bradley, Hayter & Link, 2013). We adopt a general linear model, similar to that of Rogers, Yin, & Hoffman (2000), and Friedman & Silberman (2003).

general understanding of the underlying process helps to understand how different characteristics may influence the various technology transfer activities. Technology transfer in the academic environment is lengthy; years may pass between submission of an invention disclosure, protection and marketing, and execution of a license (Swamidass & Vulasa, 2009). Invention disclosures are a critical input (Siegel, et al., 2003; Friedman & Silberman, 2003), driven by faculty engagement and the entrepreneurial culture of the university (Bercovitz & Feldman, 2008). Disclosures from faculty entrepreneurs are the lifeblood of startups (Jensen & Jones, 2011), and institutions with higher disclosure levels engage in more licensing activity and have higher licensing revenues (Feldman & Bercovitz, 2010). The timeline between invention disclosure and commercialization creates a pipeline effect–disclosures received in one year may be patented (or not) in a subsequent year and licensed to an existing company or a startup formed in yet another year.

Inventions developed at the university can only be commercialized for the benefit of the institution if they are first disclosed to the TLO (step 1 in figure 4.1 above). The formal process of disclosing an invention to the TLO starts with an invention disclosure report, which contains critical information about the invention and establishes its conception date (McGee, 2007). Such disclosure is specifically required by the Bayh-Dole Act when the invention results from federally funded research, but many inventors may not heed or even be aware of this requirement (Siegel, Waldman, Atwater & Link, 2004). TLO staff must engage with faculty researchers and the campus community to build awareness of this federal requirement as well as the university policies and practices regarding technology transfer (McGee, 2007). Higher levels of TLO engagement with university researchers has a positive influence upon invention disclosure submission (Feldman & Bercovitz, 2010), suggesting TLOs able to effectively engage with individual researchers and coordinate with other campus functions may have a positive influence upon this metric.

Prior studies indicate that invention disclosures are correlated with higher research funding and faculty quality at the university; the quality of the inventor a key determinant in both disclosure submission rates and later successful patenting and commercialization efforts (Thursby & Kemp,

2002; Jensen, Thursby & Thursby, 2003; Friedman & Silberman, 2003; Powers & McDougall, 2005a &b; Jensen & Jones, 2011). University inventors will bring disclosures to the TLO if such technology transfer efforts are supported by the policies and culture of the university, and the inventors feel they can benefit from that interaction (Markman, Phan, Balkin & Gianiodis, 2004 & 2005a; Chukumba & Jensen, 2005). Perceptions of the commercialization capabilities of the TLO are critical (Bercovitz & Feldman, 2008); inventors must have confidence the TLO has the necessary capabilities to conduct thorough commercial and intellectual property (IP) analyses of their inventions and to make connections with industry to facilitate licensing (McGee, 2007).

Once a disclosure is received by the TLO, an evaluation is done for commercial marketability of the invention and to determine if IP protection can bring additional value (step 2 in figure 4.1). Understanding technical details and how the invention relates to other work in the field is critical in determining if the invention is patentable, and how it might enter a commercial market (McGee, 2007). This initial analysis gathers information on how the invention might be utilized and its value in the marketplace, and on potential licensees (MacWright & Ritter, 2007). TLO access to information that enables proper commercial evaluation, and the skills and capability to take advantage of that information are vital for successful licensing and startup efforts (Owen-Smith & Powell, 2003, p. 1707). Subject matter expertise within the TLO may contribute by providing knowledge of connections to industry and professional networks, facilitating market evaluation and potential subsequent licensing efforts. TLO ability to quickly conduct market analysis and identify licensees speeds time to licensing and increases revenues (Markman, et al., 2005a), indicating the importance of a broad array of business skills in quickly moving a university invention through the technology transfer process.

If an invention is determined to be commercially viable, the TLO engages in efforts to identify and protect any IP to aid in the commercialization process (step 3 in figure 4.1), which may consist of any combination of patents, copyrights, trademarks, or trade-secrets. Siegel, Veugelers and Wright (2007) recommend TLOs ensure IP is "clean, well defined, and protected" before marketing

and licensing the invention (p. 655), minimizing potential financial risk to licensees of university inventions for IP infringement. Marketing activities in this third stage may include outreach and communication with inventor networks. Networking and marketing skills are helpful in engaging with inventor networks and targeted industry sectors, and to connect with prospective licensees and pitch a licensable technology (Hersey, 2007). Legal expertise is necessary for the various forms of intellectual property protection and to address the federal, state and local regulations governing the university's commercialization efforts (O'Connor, Graff, & Winickoff, 2010). Subject matter expertise within the TLO helps differentiate the invention for patent protection and identify its value to potential licensees (Owen-Smith & Powell, 2003). All of these skills discussed above are important in protecting and commercializing university inventions, and may have an influence on different technology commercialization outcomes.

When a party expresses interest in commercializing an invention, licensing discussions begin (step 4 in figure 4.1). There is a wide variety of contractual and legal obligations, rights and considerations that form licensing agreements, requiring business, legal, and financial knowledge (Bobrowicz, 2007). Negotiation, business strategy and financial skills similar to those found in venture capital firms are important for understanding commercialization goals and in finalizing licensing deals (Litan & Cook-Deegan, 2011). If the licensee is a university startup, business development skills in the TLO may be helpful for crafting business plans, procuring investment capital, and providing assistance in building management teams; described as the three critical elements for successful startups (Merrill & Mazza, 2010). TLOs may be able to increase potential for both academic as well as commercial success if appropriately staffed and organized (Siegel, et al., 2007; Siegel, 2012; ipHandbook, 2012), suggesting a variety of educational backgrounds and skills in business commercialization may influence the technology process and its outcomes in different ways.

Organizational Characteristics in Technology Transfer

Organizational structures generally reflect processes of decision making, coordination and behavioral routines of individuals (Lam, 2000), suggesting the reporting structure of the TLO and individual skills may reflect the office's capabilities and coordination with other units across the university. Previous studies on TLO organizational characteristics find reporting structures and coordinating capabilities of the TLO enable relationship building with other functional units within an organization (Bercovitz, et al., 2001; Feldman & Bercovitz, 2010), positively influencing TLO outcomes. A TLO with an autonomous organizational structure and ability to coordinate with external resources facilitates startup activity (Markman, Gianiodis & Phan, 2009); suggesting the office which drives the coordination capability of the TLO is potentially an important influence on commercial outcomes.

Specialized knowledge and skills developed through educational programs and experience have a positive influence upon an individual's job responsibilities (Rodan & Galunic, 2002); suggesting different educational backgrounds of TLO directors may have an influence upon the various stages of the technology transfer process and its outcomes. As the tenure of a TLO director increases, prior work suggests their integration within the university expands, creating a positive influence upon invention disclosure submission (Feldman & Bercovitz, 2010). Specialized knowledge developed over time is embodied in tacit knowledge (Galunic & Rodan, 1997), and experiential learning may facilitate activities of the TLO as commercialization activities become routine. Past successes have a positive influence on subsequent outcomes (Owen-Smith & Powell, 2001), suggesting prior experience and successes in licensing and startup formation may have a positive influence upon subsequent activities of the university TLO.

Institutional characteristics can also contribute to differences among universities in technology transfer outcomes. Indicators for private/public, the presence of a medical, engineering or law schools, and research funding levels are used in previous studies to account for institutional differences that may have an influence on invention disclosure and university technology transfer

efforts (Thursby & Thursby, 2002; Carlsson & Fridh, 2002; Jensen et al., 2003; Feldman & Bercovitz, 2010). Industry sponsored research at universities has a positive influence upon startup activity (Powers & McDougall, 2005a; Chukumba & Jensen, 2005). The age and size of the TLO can also influence technology transfer outcomes; however previous research findings are mixed. Some find positive correlations between older TLOs and licensing and startup formation (Friedman & Silberman, 2003; Powers & McDougall, 2005a & 2005b; Chukumba & Jensen, 2005; O'Shea, et al., 2005), while others find older TLOs less effective at startup creation (Markman, et al., 2004). Findings for TLO size are also varied; some studies show larger TLOs may be less effective or have little influence upon licensing and startup formation (Thursby & Kemp, 2002; Chukumba & Jensen, 2005); while others show larger TLOs to be more effective at licensing and generating revenues and startups (Siegel, et al., 2003; Siegel, et al., 2008; Markman, et al., 2009; Jensen & Jones 2011). Institutional characteristics are included with this analysis; indicators for private universities, the presence of medical and law schools as well as the age of the TLO as a proxy for experience.

Organizational Structure

Organizational reporting structures of the TLO may have an influence upon various technology transfer outcomes. The degree of centralization of an office has an impact of the organizational effectiveness and ability of the office to manage information flow (Zheng, Yang, McLean, 2010); this suggests that how a TLO is organized within the university, and its ability to make decisions regarding licensing negotiations, may have an effect upon technology transfer outcomes. Decision and coordination structures identified from the field of organizational science and previously used to study TLOs: centralized, decentralized, and matrix/multiple, respectively (Bercovitz, et al., 2001), evaluate how different TLO reporting structures may coordinate efforts with the larger university environment. The increased integration and coordination capacity of a TLO with a matrix decision structure can have a positive effect on invention disclosures (Bercovitz, et al., 2001), and effective TLO integration with other university functions even with lower autonomy of the

TLO can have a positive influence on licensing activity (Feldman & Bercovitz, 2010). Financial organizational structures of TLOs are analyzed in another study to determine their potential influence upon licensing and startup activity (Markman, et al., 2005a). Three financial structures are considered: whether organized and supported as an integral unit within the university (the traditional structure), organized as an external non-profit (501(c)3 organization, or as a for-profit structure focused upon economic development and university startups. The study finds different financial structural forms of TLOs can have an influence upon technology transfer outcomes and the speed at which they are transferred to the public. Traditional forms of TLOs have a negative relationship with both revenues and startup formation when compared to the non-profit TLOs; the for-profit form of the TLO had no significant direct relationship; however this latter form did have a significant influence upon reducing time to a startup formation, while a traditionally organized TLO significantly increased time to a startup formation (Markman, et al, 2005a). In evaluating use of equity as a licensing mechanism, Feldman, et al., (2002) find that self-funded TLOs are less likely to utilize equity as a licensing mechanism than otherwise funded offices, potentially due to the short term focus upon obtaining a revenue stream to meet obligations for operating budgets. Markman, et al., (2009) note the choice of organizational form can pose dilemmas for university administration; centralization of a university TLO provides standardization and reliability, but may restrict the ability of the TLO to negotiate licensing contracts in response to dynamic market conditions. Their study finds low autonomy structured TLOs are negatively related to licensing revenues, while high autonomy TLOs are significant and positively related to startup formation (Markman, et al., 2009), suggesting the ability of TLOs to coordinate with external resources and form independent ties with the local industry, entrepreneurs, investors and other resources may have a positive influence on startup formation. These prior studies provide support for further evaluation of different TLO organizational reporting relationships for variation in technology transfer outcomes. We analyze the specific reporting structure of the TLO, as the office to which the TLO reports is likely to have say in the goals and objectives of TLO, and may have an influence upon its outcomes.

When TLOs report to the institutional leader, the importance of technology transfer is emphasized, sending strong signals of legitimacy to the campus. This type of centralized reporting structure for the TLO can benefit from strong leadership driving coordination efforts (Bercovitz, et al., 2001), potentially influencing all stages of technology commercialization. A TLO reporting to a research office may be focused upon coordinating with other research support units, academic researchers and funding agencies; increasing awareness of the TLO with academic researchers, with a potential positive influence on invention disclosure activity. TLOs organized under the office of research may have access to industry networks from industry support of research, increasing opportunities for licensing. A TLO organized under an economic or business development office structure may be able to coordinate efforts with other externally focused departments (such as alumni offices or public relations) as well as entities and resources outside of the university. A TLO focused on economic development activities, with high autonomy in decision making can have a positive influence upon startup formation (Markman, et al., 2009); potentially through access to external business and entrepreneurial support mechanisms. A TLO reporting to multiple operations may positively influence technology commercialization outcomes through increased visibility and coordination efforts. The effectiveness of the TLO in managing the increased complexity generated from multiple reporting relationships (Bercovitz, et al., 2001) may moderate that influence. The different organizational structures may focus efforts of the TLO on strategic technology commercialization outcomes, and suggests there may be some variation in commercialization outcomes further described in table 4.1 below:

Table 4.1 Predicted relationships between reporting structure and technology transfer outcomes

		Reporting Structures			
		Research	Leadership	Econ/Bus Dev.	Multiple
Input	Invention Disclosures	+ Increased coordination with research faculty and funding sources	+ Strong signal in support of tech transfer	- Potential less direct interaction with researchers	+ Increased coordination activities may increase interface with inventors
Commercial path	Licenses	+ Coordination with faculty researchers provides access to increased network for licensing	+ Depends upon strategic direction of leadership, expect positive relationship	- Less coordination with researchers may reduce access to networks and funding agencies	+ Increased coordination with internal & external entities may create opportunities for licensing
	Startups	- Less coordination with external organizations may limit access to entrepreneurs and investment	+ Depends upon strategic direction of leadership, expect positive relationship	+ Increased coordination with units focused on econ development, access to external support	+ Increased coordination with multiple units may provide increased opportunities for startup activities

Educational Background

The technology transfer process requires a variety of skills: knowledge of university research, business marketing and commercialization skills, networking and links to bus development organizations (Siegel, et al., 2003; Markman, et al, 2005a; McGee, 2007). Identifying professional degrees and skillsets that influence the technology transfer process and its outcomes can inform those who wish to strategically align skills of the TLO with other university characteristics, in order to target particular outcomes. Educational training provides expert understanding on how resources can be managed and leveraged in industry (Galunic & Rodan, 1997); suggesting educational background differences among TLO directors may promote certain activities over others. To date, there has not been an examination of the TLO director's education as an influence on technology transfer activities reported in the literature. Several studies identify TLO business and commercialization skills as important to academic technology transfer efforts, particularly for startup formation (O'Shea, et al., 2005; Siegel & Phan, 2005; Siegel, et al., 2007; Swamidass, 2013), but for licensing efforts as well (Markman, et al., 2005a). Many business and commercialization skills may be developed through specific educational training, or through experience working with industry, entrepreneurs, or investment managers. The importance of hiring personnel in the TLO with a variety of these key

business qualifications is important for successful commercialization efforts (ipHandbook, 2012). High salaries of TLO licensing professionals, used as a proxy for commercialization skillsets in the TLO, in Markman, et al.'s (2009) analysis finds that higher salaries for those individuals charged with licensing the university's intellectual property have a positive relationship with both licensing revenues coming into the university and startup formation. Suggesting highly skilled licensing professionals who are able to command higher salaries may provide broad-based commercialization skills that can positively influence outcomes from the technology transfer process. A deficit of commercialization skills, (specifically financial, technical, commercial industry linkages and entrepreneurial backgrounds) is identified as a potential barrier to successful academic technology transfer activities (Metz, et al., 2000; Siegel, et al., 2004; 2007; 2012; Markman, et al., 2005a; Litan & Cook-Deegan, 2011, Swamidass, 2013). The findings from these previous studies provide justification for evaluating the variety of skillsets of the individuals responsible for managing TLOs; their educational degree is used as a proxy for this difficult to measure characteristic.

Calls in the literature for an expansion of business and commercialization skills suggest a TLO director with an MBA degree may facilitate commercialization efforts due to training in strategic and business planning, financial management, asset valuation and other business related skills, which may facilitate both licensing and startup activity. Dissimilar cultural and educational norms (Zheng, Yang & McClean, 2010) may create a barrier for a TLO director with an MBA in obtaining invention disclosures from PhD research faculty, while a TLO director with a PhD may be able to positively influence invention disclosure submission. Subject matter expertise developed through a PhD in the scientific field of an invention may provide access to industry or practitioner networks, potentially increasing licensing outcomes. TLO directors with legal degrees (JD) may have advanced IP & legal contract skills, which may not be an advantage for licensing efforts if those skills result in a tougher negotiation stance as suggested by Siegel, et al.'s (2003) field research. The presence of a law school is shown to have a positive relationship with university startup activity (Feldman & Bercovitz, 2010), suggesting there may be some positive correlation between TLO

directors with a JD and startup formation. A JD may be able to help university startups with business legalities and contractual work that can facilitate university startup formation. TLO directors who have a bachelor's degree are presumed to be in leadership positions due to experience and skills that make those individuals appropriate for director responsibilities; such experiential skills may also have a positive influence on all stages of technology commercialization activities. TLO directors with different educational backgrounds may have variation in commercialization outcomes further described in table 4.2.

Table 4.2 Predicted relationships between TLO Director's education and outcomes

		TLO Director's education			
		PhD	Legal (JD)	MBA	BS
Input	Invention Disclosures	+ Direct interaction with researchers, common educational foundation	- Less coordination with research faculty, skills related to IP protection	- Dissimilar cultural and educational norms from research faculty	+ Coordination with research faculty, previous experience
Commercial path	Licenses	+ Scientific domain can facilitate placement with industries best capable of utilizing invention	- Increased legalities in agreements add difficulties in getting to license finalization.	+ Marketing skills, industry contacts, and financial knowledge	+ Depends on previous licensing experience, industry networks
	Startups	+ No 'broad based' commercial skills; scientific knowledge can facilitate transfer to startup	+ Access to contractual and legal resources may facilitate startup activity	+ Market, financial and commercialization knowledge, access to entrepreneurs and investment	+ Depends on previous entrepreneurial experience, networks

Model

In order to evaluate the relationships between TLO characteristics and technology licensing outcomes, each dependent variable is modeled as a linear function:

$$Y_{it} = \beta_0 + \beta_{it} X'_{it} + \beta_i C'_i + \beta_i O_i + \beta_i E_i + u_{it}$$

Where Y_{it} is the dependent variable being measured: invention disclosures, licenses and startups for each university (i), for each year (t). X'_{it} is a vector of university and TLO variables that change over

time: total research expenditures, industry funding density, age and size of the TLO. C'_i is the vector of institutional and TLO fixed variables that do not change over the years of this analysis: indicators for private schools, the presence of medical, engineering and law schools and the historical measure of each dependent variable. The tenure of the TLO director is included in X'_{it} to evaluate how experience on the job may influence technology licensing activities. O_i is the vector of fixed indicators for organizational reporting structure of the TLO (institutional leadership, research office, economic or business development, or multiple reporting structure) as reported by the universities in the study in 2007. We use this indicator to compare the reporting structure's influence on technology commercialization activities from 2008-2010. E_i is the vector of fixed indictors for the TLO director's most recent terminal degree: bachelor's (BS) degree, MBA degree, Law (JD) degree, or PhD.

Data & Method

In evaluating the TLO characteristics on technology transfer metrics, data are used from two survey instruments: the AUTM annual licensing survey and Feldman and Bercovitz's (2010) survey of AUTM respondents, collected in 2007. Data for analysis is collected for 76 universities for a 3 year period (2008-2010) to analyze the influence of the reporting structure and TLO director's educational background in 2007 on subsequent invention disclosure, licensing and startup activity. We limit data to a three year period to minimize potential variability that may be introduced by TLO reorganizations due to administrative or other changes (Feldman & Bercovitz, 2010). The AUTM annual licensing survey provides yearly measures for the dependent variables and information on total research funding, industry funding, TLO age and size. Industry research funding divided by total research dollars provides a percentage of industry funding, and a ratio of licensing staff per million of total research funding provides a normalized variable to control for the size of the university and the size of the TLO. Feldman and Bercovitz's (2010) survey of AUTM members in 2007 provides the independent variables of interest: the TLO reporting structure, last educational degree of the TLO director, and the directors' tenure in their position. This survey also provides institutional controls

indicators for private universities and the presence of medical and law schools. Feldman and Bercovitz's (2010) study provides some understanding of how heterogeneity in organizational structures and capabilities of university TLOs might influence the technology transfer process; this current study builds upon their findings. Additional primary research via university websites and social media validates and expands the data; filling in missing variables. A list of the dependent and independent variables of interest for this current study is included in table 4.3 below, with descriptive names, the percentages for each structure and education, the variable type, and source of the data. A full set of descriptive statistics for all variables included in this analysis is included in table 4.9.

Table 4.3 Dependent and Independent Variables

Variable		Percentage	Type	Source
Dependent variables (yearly measures):				
Invention Disclosures	Invention Disclosures received		Continuous (logged averages)	AUTM STATT
Licenses	Executed Licenses			
Startups	Startups from the university			
Independent variables:				
Reporting Office				
Report to Research	Research Office	47 (62%)	Binary	Feldman and Bercovitz survey, independent verification
Report to Leader	Chancellor/President	12 (16%)		
Report to Econ/Bus	Economic/Business Development.	11 (14%)		
Report to Multiple Off.	Multiple Offices	6 (8%)		
Education & Experience				
Director PhD	PhD degree	30 (40%)	Binary	Feldman and Bercovitz survey, independent verification
Director Lawyer	Law degree	14 (18%)		
Director MBA	MBA	18 (24%)		
Director BS/BA	Bachelors	14 (18%)		
Director Tenure	Years in current position		Continuous	

Dependent Variables

The dependent variables of this study include invention disclosures received, licenses completed, and startups formed. Patents are not included in the regression analysis as decisions regarding intellectual property protection can be driven by many factors including budget availability, patenting strategies, decisions by patent committees and licensee expectations, among others (Livne, 2007). The dependent variables change from year to year and across universities, both within the

current sample as well as across the population of university respondents to the AUTM annual survey. For the representative universities in our sample from 2008-2010, annual invention disclosure submissions ranged between 6 and 513, US issued patents between 1 and 155, licenses between 1 and 104, and startups between 0 and 19; providing some indication of the range of research universities included in this analysis. When compared to the AUTM population, the 76 universities included in this study seem to reflect the general characteristics of the population of AUTM respondents. Between 2008 and 2010, an average of 148 different US research universities participated in the AUTM annual licensing surveys. Within those participating institutions, annual invention disclosures ranged between 1 and 744, US issued patents between 0 and 180, licenses between 0 and 214, and startups between 0 and 33. Comparisons between the AUTM population of research universities and the sample evaluated in this analysis on the dependent variables and independent variables analyzed in this study are further described below in table 4.4.

Table 4.4 Study Sample Comparisons to AUTM Population, 2008-2010

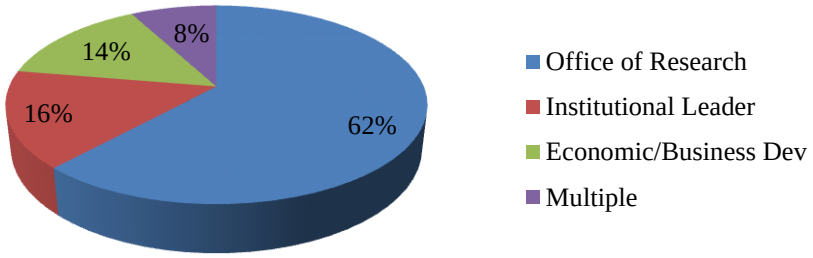
	AUTM Population				**Study Sample**			
Variable	**Obs**	**Mean**	**Min**	**Max**	**Obs**	**Mean**	**Min**	**Max**
Invention Disclosures	148	110.19	1	744	76	111.02	6	512.67
Licenses	148	23.15	0	214	76	24.98	.67	103.67
Startups	146	3.46	0	33	76	3.63	0	19
Issued US Patents	147	20.57	0	180	75	25.42	1	155
Licensing Staff/Total Research Funding ($M)	145	0.03	0	0.18	76	0.025	0.006	0.11
Licensing Staff	145	5.38	0	60	76	5.90	0.5	60
Total Research ($M)	147	$291	$3	$2,547	76	$327	$16	$1,518
Industry Research %	147	7%	0%	38.5%	76	10.8%	1.0%	34.7%
TLO Age	147	20.89	0	85	76	20.89	1	82

Independent Variables

Organizational reporting structures for the university TLOs in this current study consist of four reporting types: 1) to the university research function, 2) to an economic or business development function, 3) to the leadership of the university, and 4) to multiple offices. Forty-seven university TLOs report to the research function within the university, 11 report to an economic

development or business development function, 12 report directly to the leader of the university, while 6 report to multiple university functions (figure 4.2).

Figure 4.2: TLO Organizational Reporting Structure



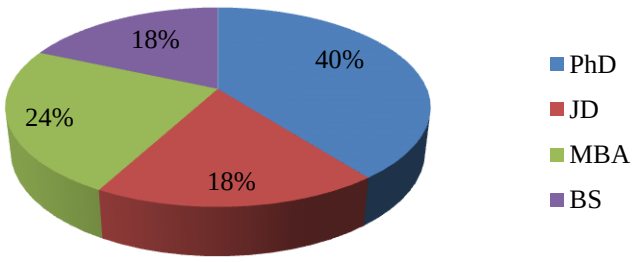
Average invention disclosures received, licenses completed and startups formed for each of the four organizational structures evaluated in this study are presented in table 4.5 below. On average from 2008-2010, TLOs reporting to the office of research received 114 invention disclosures per year, those reporting to the institutional leader received 151, those reporting to an economic/business development office 108, and those reporting to multiple offices 147. In licensing activity, TLOs reporting to the office of research successfully completed an average of 23 licenses each year, those reporting to the institutional leader completed 27, those reporting to an economic/business development office 23, and those reporting to multiple offices 40. Startup activity is most for TLOs reporting to the office of research; those offices able to startup about 3 each year, while those TLOs reporting to the institutional leader started an average of 4, those reporting to an economic/business development office an average of 5 each year, and those reporting to multiple offices an average of about 3 per year.

Table 4.5 Data Statistics by TLO Organizational Structure, 2008-2010

Invention Disclosures	**Obs**	**Mean**	**Min**	**Max**
Office of Research	47	114	13	513
Leader	12	151	11	338
Econ/Bus Dev.	11	108	6	311
Multiple	6	147	33	357
Licenses	**Obs**	**Mean**	**Min**	**Max**
Office of Research	47	23	1	104
Leader	12	27	2	81
Econ/Bus Dev.	11	22	2	69
Multiple	6	40	13	50
Startups	**Obs**	**Mean**	**Min**	**Max**
Office of Research	47	3	0	18
Leader	12	4	0	11
Econ/Bus Dev.	11	5	0	19
Multiple	6	3	0	4

The multiple educational backgrounds of the TLO directors analyzed in this study reflect the widespread and multidisciplinary nature of university commercialization efforts, and the range of multidisciplinary skills that can support the technology transfer process. Thirty TLO directors in the current sample have PhDs, 14 have legal degrees (JD), 18 have MBA degrees, and 14 TLO directors have BS degrees (figure 4.3).

Figure 4.3: TLO Director Education



Average invention disclosures received, licenses completed and startups formed for each of the TLO director's different educational backgrounds from 2008-2010 are presented in table 4.6. On average from 2008-2010, TLO directors with MBA degrees received 145 invention disclosures per

year, TLO directors with JDs received an average of 119, TLO directors with PhDs an average of 118, and TLO directors with bachelor degrees averaged 100 per year. In licensing activity, averages are highest for TLO directors with bachelor's degrees, at an average of about 30 licenses per year, TLO directors with MBA degrees averaged about 28 licenses per year, JDs averaged about 23 per year, and an average of 22 licenses for TLO directors with PhDs. Average startup activity is highest for TLO directors with MBAs, at about 5 startups formed per year, while those TLO directors with JDs average 4, and TLO directors with PhDs and bachelor's degrees averaged about 3 per year. Average length of job experience in the position for TLO directors is greatest for those with bachelor degrees at about 10.5 years, second for those with MBA degrees at 9.78 years; PhDs had about 7.1 years of average job tenure experience, and TLO directors with JDs average about 6.25 years in their position.

Table 4.6 Data Statistics by TLO Director Education, 2008-2010

Invention Disclosures	**Obs**	**Mean**	**Min**	**Max**
MBA	18	145	12	513
Lawyer	14	119	32	357
PhD	30	118	6	359
BS	14	100	13	450
Licenses	**Obs**	**Mean**	**Min**	**Max**
BS	14	30	1	104
MBA	18	28	2	69
PhD	30	22	2	49
Lawyer	14	23	2	81
Startups	**Obs**	**Mean**	**Min**	**Max**
MBA	18	5	0	19
PhD	30	3	0	10
Lawyer	14	4	1	11
BS	14	3	0	9
Job Tenure	**Obs**	**Mean**	**Min**	**Max**
BS	14	10.5	3	26
MBA	18	9.78	2	23
PhD	30	7.1	3	13
Lawyer	14	6.25	2.5	13

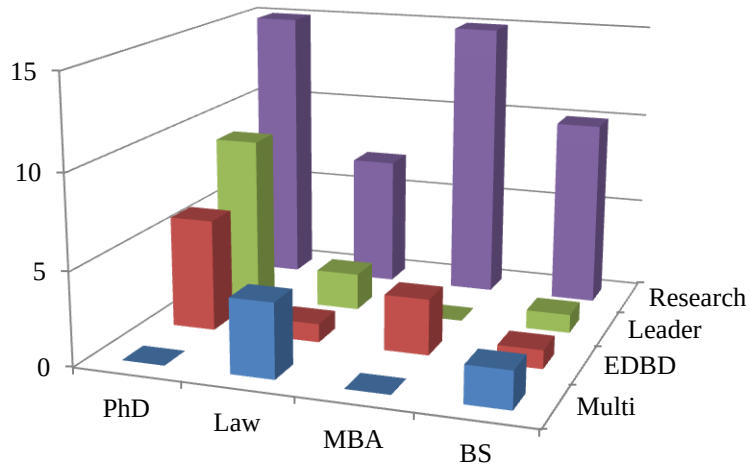
Between the organizational reporting structure and the TLO director's education, there are 16 possible combinations that could result. The two most common organizations in this study are TLOs

reporting to an office of research with a PhD director (15), or TLOs reporting to an office of research with an MBA director (15). The different combinations of TLO organizations are shown in table 4.7 & figure 4.4. We compare the two most commonly found organizations with the other to determine if there may be any significant difference the most common TLO structures and any of the others. The results from this comparison are further discussed below.

Table 4.7 Combinations of Organizational Structure and Director's Degree

Reporting Office/ Director's Educ.	Multi	EDBD	Leader	Research	N
PhD	0	6	9	15	30
Law	4	1	2	7	14
MBA	0	3	0	15	18
BS	2	1	1	10	14
N	6	11	12	47	76

Figure 4.4 Combinations of Organizational Structure and Director's Degree



The two most commonly organized structures are TLOs organized under the office of research, with a TLO director who has a PhD education, or a TLO director with an MBA. These two dominant structures are compared against all others to determine if there is any statistical difference

between the two most commonly found TLO organizations and the remaining in obtaining invention disclosures from faculty, licensing to industry, or forming startups. The results of these comparisons are discussed in the results section below.

Controls

Other institutional characteristics such as private versus public status and the presence of a medical school and law school are included to help control for any influence they may have upon TT efforts in addition to controlling for university differences. Many previous studies have included public or private indicators to control for differences and their potential influence on licensing and startup activity (Friedman & Silberman, 2003; Chukumba & Jensen, 2005; Markman, et al., 2005a & 2009; Bulut & Moschini, 2009). Medical schools are often included in prior analysis due to the high volume of biomedical research that has garnered the attention of industry and produced high revenue generating licenses for universities (Bulut & Moschini, 2009). We include an indicator for the presence of a law school due to the positive correlation found by Feldman and Bercovitz (2010) between the presence of a law school and university startup activity, and the potential accessibility to on-campus legal resources which may assist the technology transfer process and its outcomes. The presence of an engineering school was also considered for potential inclusion; however tests for significance indicated this characteristic had little direct impact upon disclosure activity, licenses or startups for these 76 universities. Twenty-one universities in the current study (28%) are identified as private institutions. Fifty (66%) have a medical school, and 34 (45%) have a law school. Twenty-seven (36%) have both academic programs, while 23 (32%) have a medical school without a law school, and 7 (9%) have a law school with no medical school.

The annual research levels of the 76 universities range from about $16 million to about $1.5 billion, while the full set of universities participating in the AUTM annual licensing survey during this same time frame ranges from $3.2 million to about $5.4 billion in research funding, indicating the sample in the current study is missing the highest and lowest funded universities in this analysis (see

table 4.4). A ratio of the number of full-time licensing staff per million in research funding normalizes the resource commitment for technology transfer. This ratio stands at 0.03 for the AUTM population, indicating on average, there is a licensing staff member in the TLO for every $33 million in research funding. For the sample in this analysis, this ratio stands at 0.025 or about 1 licensing staff member for every $40 million in research funding. Industry sponsored research percentages (industry research$/total research$) for the universities in the current study average about 10.8% during 2008-2010, ranging from 1% to 34.6%, similar to the AUTM population, which averaged about 7% industry funding, ranging from 0% to38.5%. Industry research percentages suggest the study sample includes universities with both high and low percentages of industry funding across US universities and reflect the AUTM population. The age of the TLO provides additional controls for general experience in academic technology transfer, and ranges from a single year to 82 years of operation in the current sample; the AUTM population ranges from 0 to 85.

Previous experience of the TLO can facilitate subsequent efforts (Friedman & Silberman, 2003; O'Shea, et al., 2005; Jensen & Jones, 2011); suggesting measures of previous activities can be useful for the current analysis. Lagged averages for invention disclosures and licenses from 2003-2006 are included to model the pipeline process flow of academic technology transfer as identified in figure 4.1. Invention disclosures from 2003-2006 are included as historical inputs for licensing activity and startup formation. In estimating startup formation, historical license activity from 2003-2006 is also included to evaluate how prior licensing activity might influence subsequent startup efforts. The historical variables are logged to address over dispersion, normalize the data and reduce variable variance, and minimize multicollinearity. The control variables and their sources are further described in table 4.8 below with descriptive names, type of variable, and percentages.

Table 4.8: List of Controls

Control Variables:		Percentage	Type	Source
University Controls:				
Private	Indicator	21 (28%)	Binary	Feldman and Bercovitz survey
Medical school	Indicator	50 (66%)		
Law school	Indicator	34 (45%)		
Technology Licensing Office Controls:				
TLO Age	Experience		Count	AUTM Statistics Access for Tech Transfer (STATT)
# Licensing staff per million in research $	Ratio		Continuous	
Industry research %	Industry % of research		Continuous	
History and Pipeline Controls:				
Past Invention Disc. & Past Licenses	Logged Averages (2003-2006)		Continuous	STATT

Descriptive statistics of the variables utilized in the model (table 4.9) help to understand the variety of institutions included in the current study. The dependent and historical variables for invention disclosures, licenses, and startups are averaged to account for internal unobserved university characteristics, and logged to address any non-linearity issues.

Table 4.9 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Range	Frequency
Log Avg. Inv. Disclosures 2008-2010	76	4.401166	0.9566012	1.95-6.24	
Log Avg. Licenses 2008-2010	76	2.810995	1.022706	0.511-4.65	
Log Avg. Startups 2008-2010	76	1.279339	0.6927406	0-2.995	
Log Avg. Disclosures 2003-06	75	4.318397	0.9007889	2.3-6.22	
Log Avg. Licenses 2003-06	75	2.812711	1.02229	0.69-5.12	
Research Office	76	0.1578947	0.3670652	0-1	47
Institutional Leader	76	0.6184211	0.4890018	0-1	12
Economic or Business Dev.	76	0.1447368	0.3541731	0-1	11
Multiple Reporting	76	0.0789474	0.2714484	0-1	6
PhD	76	0.3947368	0.4920419	0-1	30
Lawyer	76	0.1842105	0.3902316	0-1	14
MBA	76	0.2368421	0.4279695	0-1	18
BS/BA	76	0.1842105	0.3902316	0-1	14
Director years at job	76	8.190789	4.917294	2-26	
Private	76	0.2763158	0.4501462	0-1	21, 55 public
Medical school	76	0.6578947	0.4775669	0-1	50
Law School	76	0.4473684	0.500526	0-1	34
Average Industry Res %	76	0.1077797	0.0809665	0.01%-34.66%	
TLO age	76	20.89474	14.37273	1-82	
Licensing Staff /Total Res. $M	76	0.025	0.0183156	0.006-0.11	

Table 4.10 below provides the Pearson correlation coefficients between the dependent and the independent variables of interest. Table 4.24 in Appendix C provides the Pearson correlations for all variables included in the model, including the logged historical averages and additional institutional and TLO controls. The technology licensing outcomes are positively related to each other; specifically invention disclosures are highly correlated with both licensing and startup activity, highlighting the pipeline effect of the technology transfer process, and of invention disclosures as the primary input into this process; no other commercialization activity happens without this critical first step (Bercovitz & Feldman, 2008). Tests for multicollinearity after each regression suggest an absence of strong correlation between most of the independent variables, with variance inflation factors less than 10 for each. The historical averages are highly correlated with each other and the dependent variables (see table 4.24 in Appendix C).

Table 4.10 Pearson Correlations, Dependent and Independent Variables

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
Log Avg. Inv. Disc (a)	1											
Log Avg. Licenses (b)	0.79	1										
Log Avg. Startups (c)	0.75	0.55	1									
Office of Research (d)	-0.10	-0.11	-0.15	1								
Institutional Leader (e)	0.11	0.03	0.06	-0.55	1							
Economic/Bus. Dev. (f)	-0.07	-0.06	0.14	-0.52	-0.18	1						
Multiple Reporting (g)	0.11	0.24	0.00	-0.37	-0.13	-0.12	1					
Director PhD (h)	0.01	0.00	-0.02	-0.20	0.31	0.13	-0.24	1				
Director JD (i)	0.02	-0.08	0.08	-0.12	-0.02	-0.10	0.36	-0.38	1			
Director MBA (j)	0.06	0.03	0.13	0.25	-0.24	0.03	-0.16	-0.45	-0.26	1		
Director BS/BA (k)	-0.10	0.05	-0.20	0.09	-0.11	-0.10	0.11	-0.38	-0.23	-0.26	1	
Director tenure (l)	0.01	0.10	-0.09	0.08	-0.11	-0.12	0.18	-0.19	-0.19	0.18	0.22	1

Method

The current study uses ordinary least squares (OLS) to model each metric (invention disclosures, licenses and startups) as a function of university and TLO characteristics, including the variables of interest: the organizational structure of the TLO, educational background, and tenure of the TLO director. Historical measures for are included to model the pipeline effect and evaluate how

past efforts might influence subsequent activities. Regression results for one set of base-line comparisons are provided in table 4.11 below, additional tables can be found in Appendix C.

The averaged variables are transformed (increased by 1 and logged) to normalize the data and to correct for skewness and over dispersion. Logging variables is a common transformation practice in normalizing data; adding one to the transformation on the dependent variable (ln(1) = 0) allows the inclusion of any observations of zero for that metric. Detailed summary statistics and histograms of the dependent variables are included in Appendix C for both original and logged forms. Interpreting the coefficient estimates for the independent variables when the dependent variables are log transformed requires a reverse transformation to understand how changes might affect the different commercialization outcomes. With a log transformed dependent variable, the effect size can be shown by $100(e^{\beta_i} - 1)$, to measure the impact of a 1 unit increase in the independent variable on each of the technology transfer outcome measures (Cameron & Triveldi, 2010, Wooldridge, 2006). For the logged historical averages, the coefficients (β_i) are elasticities, and measure the expected percentage change for each of the dependent variables associated with a potential 1% increase in the lagged historical variable (Green, 2003). The transformations are included in the tables and indicate the effect sizes for a one unit change in each of the independent variables.

Results

The results suggest the different TLO reporting structures and different educational backgrounds of the TLO director may have an influence upon academic technology commercialization outcomes. Results presented in table 4.11 utilize the office of research reporting structure and a TLO director with a PhD educational background as initial baseline characteristics for comparison. Results comparing each TLO organizational structure and educational background of TLO directors to others are presented in tables 4.12 and 4.13 below. The results show how the different reporting structures and educational characteristics may influence activities along the technology transfer process relative to the others. OLS results tables for the remaining baseline

comparisons can be found in Appendix C. Implications of the findings for university administrators coordinating the technology transfer process at US research universities and those legislators involved in policy discussions regarding academic technology transfer follows discussion of the results.

Table 4.11 Regression Results, Office of Research Reporting & PhD held as comparison

OLS (08-10)	(1) Disclosures		(2) Licenses		(3) Startups	
Institutional Leader	0.171	18.65%	0.186	20.44%	0.310*	**36.34%**
	(0.300)		(0.204)		(0.142)	
Economic/Bus. Dev.	-0.394	-32.56%	-0.0288	-2.84%	0.257+	**29.30%**
	(0.329)		(0.226)		(0.143)	
Multiple Offices	0.205	22.75%	0.664+	**94.25%**	-0.0640	-6.20%
	(0.305)		(0.354)		(0.211)	
Director JD	-0.0579	-5.63%	-0.455*	**-36.56%**	0.117	12.41%
	(0.294)		(0.203)		(0.178)	
Director MBA	0.451*	**56.99%**	0.0380	3.87%	0.295+	**34.31%**
	(0.216)		(0.209)		(0.168)	
Director BS	0.0833	8.69%	0.359	43.19%	0.238	26.87%
	(0.280)		(0.273)		(0.171)	
Director tenure	-0.0237	-2.34%	-0.0103	-1.02%	-0.0115	-1.14%
	(0.0185)		(0.0147)		(0.0127)	
Private	0.393*	**48.14%**	-0.349*	**-29.46%**	-0.237*	**-21.10%**
	(0.186)		(0.154)		(0.106)	
Medical School	0.556*	**74.37%**	-0.170	-15.63%	0.0831	8.67%
	(0.212)		(0.206)		(0.122)	
Law School	0.334+	**39.65%**	0.0868	9.07%	0.269*	**30.87%**
	(0.172)		(0.178)		(0.114)	
Licensing Staff/ M$ Research Funding	-12.24*	**-1.00%**	-6.574	-1.00%	-4.966+	**-0.99%**
	(5.300)		(4.873)		(2.605)	
Industry Research %	2.303*	**9.00%**	-0.110	-0.10%	1.463+	**3.32%**
	(0.924)		(0.884)		(0.874)	
TLO Age	0.0307***	**3.12%**	0.0000600	0.01%	0.00729	0.73%
	(0.00684)		(0.00535)		(0.00447)	
Log Avg Inv. Disc.T1			0.859***	**0.858%**	0.659***	**0.658%**
			(0.0938)		(0.126)	
Log Avg Licenses T1					-0.235+	**-0.234%**
					(0.135)	
_cons	3.291***		-0.500		-1.303***	
	(0.380)		(0.458)		(0.343)	
N	76		75		75	
R^2	0.524		0.711		0.679	
adj. R^2	0.424		0.643		0.597	
F	10.38		27.80		10.12	

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A summary of results for the analysis of TLO organizational structures in table 4.12 provides a comparison of the effectiveness of each structure in relation to the others. No significant difference is indicated for invention disclosures receipt between any of the different TLO structures, suggesting other characteristics outside of the TLO may influence disclosure rates. The different structures are found to influence licenses and startup formation, however. The results from the current study finds the economic/business development reporting structure may be 23-29% more effective at startup formation than a TLO reporting to an office of research, all else being equal. When the economic/business development reporting structure is compared to a TLO reporting to the leader of the university, no significant difference is indicated for licensing and startup formation. When compared to a multiple reporting structure, the TLO reporting to an economic/business development office is found to be significantly less effective at licensing efforts, potentially 50-100% less effective at licensing the invention disclosures received than those TLOs reporting to multiple offices, all else equal. TLOs reporting to the institutional leader are also shown to be more effective at startup formation than TLOs reporting to the office of research, potentially 27-36% more effective; and more effective than TLOs reporting to multiple offices, potentially 31-45% more effective, all else equal. TLOs reporting to multiple offices may be more effective at licensing than TLOs reporting to an office of research, potentially 49-94% more effective, all else equal.

Table 4.12 Organizational Structure Comparison

Comparison Structure (Base line)	Alternate Structure Effectiveness			
	Office of Research	Econ/Bus Dev.	Leader	Multiple
Office of Research	--	Startups: **29.30%** (p<0.10)	Startups: **36.34%** (p<0.05)	Licenses: **94.25%** (p<0.10)
Econ/Bus Dev.	Startups: **-22.66%** (p<0.10)	--	NS	Licenses: **99.97%** (p<0.10)
Leader	Startups: **-26.66%** (p<0.05)	NS	--	Startups: **-31.20%** (p<0.10)
Multiple	Licenses: **-48.52%** (p<0.10)	Licenses: **-49.99%** (p<0.10)	Startups: **45.35%** (p<0.10)	--

The increased effectiveness of the economic/business development TLO reporting structure for startup formation, when compared to the TLO reporting to an office of research, provides some support for Markman, et al.'s (2009) finding that ability of the TLO to coordinate with external resources has a positive influence on startup formation. This analysis also finds TLOs reporting to the institutional leader have a positive influence upon startup formation, more so than a TLOs reporting to an office of research or multiple offices, suggesting TLOs reporting directly to the institutional leader may have a strategic focus upon startup formation, or have access to similar resources that can facilitate startup activity. We find TLOs reporting to multiple offices more effective in licensing activities during 2008-2010 than either the office of research or economic/business development reporting structure, but less effective at startup formation than TLOs reporting to an institutional leader, suggesting TLOs under multiple reporting structures may be strategically focused upon licensing, or may have access to resources that can facilitate licensing efforts.

The summary of the analysis of educational backgrounds of TLO directors in table 4.13 compares the influence of different educational backgrounds to each other for each of the technology transfer outcome measures. When compared to all other TLO directors with different educational backgrounds, directors with a legal background (JD) are less effective in licensing university inventions; potentially 37-58% less effective than those TLO directors with a PhD, potentially 39-64% less effective than TLO directors with a MBA, and potentially 56-125% less effective than TLO directors with a bachelor's degree, all else being equal. We find TLO directors with MBA backgrounds more effective at obtaining invention disclosures and at startup formation than TLO directors with PhDs, about 36-57% more effective at invention disclosure receipt, and 26-34% more effective at startup formation, all else equal. No significance difference is indicated between TLO directors with bachelor's degrees and TLO directors with PhDs or MBAs for any of the outcome measures. The negative relationship between TLO directors with JDs and licensing efforts when compared to all TLO directors with alternative educational backgrounds provides support for Siegel, et al.'s (2003) finding from their analysis of external legal expenditures and qualitative interviews that

suggest legal wrangling from lawyers may have a negative influence upon licensing efforts. Further analysis might consider the relationship between TLO directors with a JD and revenue streams received by the university, considering Siegel, et al.'s (2003) finding that external expenditures are correlated with higher licensing revenues.

Table 4.13 Educational Background Comparison

Comparison Education (Base line)	Alternate Education Effectiveness PhD	MBA	BS	JD
PhD	--	Inv. Disc.: **56.99%** ($p<0.05$) Startups: **34.31%** ($p<0.10$)	NS	Licenses: **-36.56%** ($p<0.05$)
MBA	Inv. Disc.: **-36.30%** ($p<0.05$) Startups: **-25.55%** ($p<0.10$)	--	NS	Licenses: **-38.92%** ($p<0.05$)
BS	NS	NS	--	Licenses: **-55.69%** ($p<0.01$)
JD	Licenses: **57.62%** ($p<0.05$)	Licenses: **63.72%** ($p<0.05$)	Licenses: **125.69%** ($p<0.01$)	--

Based on this analysis, TLO directors with an MBA educational background seem to be more effective in obtaining invention disclosures and forming startups when compared to TLO directors with a PhD, and more effective at licensing than TLO directors with legal backgrounds. This finding provides additional support for those suggesting a need for expanded commercialization skillsets in university TLOs (Metz, et al., 2000; Litan & Cook-Deegan, 2011; Siegel, et al., 2007, 2012; Swamidass, 2013), through hiring individuals with strong licensing, technical and commercial skills and entrepreneurial backgrounds that can facilitate licensing and startup activity (Siegel, 2012).

The estimate for the TLO director's tenure variable indicates a slight negative relationship with invention disclosures, licensing and startup activity, but is not significant. Indicators for private institutions suggest that private institutions may be more effective than public at obtaining invention disclosures (48%, $p<0.05$), however private universities may be less effective than public at licensing (-29%, $p<0.05$) or forming startups (-21%, $p<0.05$) from the disclosures received by the TLO. The presence of a medical school is also shown to have a positive influence upon invention disclosure

receipt (74%, $p<0.05$), but is not significantly related to licensing or startup formation. The indicator for the presence of a law school is shown to have a positive relationship with invention disclosure receipt (40%, $p<0.10$), and is positive and strongly significant for startup activity (31%, $p<0.05$). This supports Feldman and Bercovitz's (2010) previous finding that the presence of a law school can have a positive influence on startup formation.

Findings from previous studies indicate universities with high research funding are able to work with more invention disclosures (Thursby & Kemp, 2002; Friedman & Silberman, 2003), and are effective at licensing and startup formation (O'Shea, et al., 2005; Markman, et al., 2004; Thursby & Thursby, 2007; Bulut & Moschini, 2009; Jensen & Jones, 2011). Findings from several studies also indicate larger TLOs facilitate licensing and startup activities (Markman, et al., 2005a; Thursby & Thursby, 2007; Markman, et al., 2009; O'Shea, et al., 2005; Jensen & Jones, 2011). Larger universities may also have larger TLOs to facilitate the technology transfer process, and these two variables are highly correlated with each other (>0.73) in the current sample. In order to address this potential multicollinearity, we create a ratio of the number of licensing staff per million in total research funding. The estimate for this ratio is significant for invention disclosure receipt (-1.00%, $p<0.05$) and startup formation (-0.99%, $p<0.10$), but not for licensing activities. This negative relationship is expected, as adding more licensing staff to support technology transfer activities does not make sense without a corresponding expansion in research funding. The universities in this current study have on average about 1 licensing staff member for every $40 million in research funds. The estimate on the licensing staff/research funding ratio suggests that universities with higher ratios of licensing staff to research dollars are less effective at obtaining invention disclosures and forming startups. The effect change indicates a 1% positive change in the ratio of licensing staff to research funding may reduce invention disclosure receipt by 1%, suggesting the universities with largest staff to research funding ratio may wish to consider their allocation of resources for their levels of research funding. An interesting follow up question would be to determine the best ratio for a university to be most efficient and effective in technology commercialization efforts; to find the saturation point at

which adding additional licensing staff creates diminishing returns. The estimates on the percentage of industry sponsored research are significant and positive for invention disclosure activity ($p<0.05$) and startup formation ($p<0.10$) and suggest a one unit change in the percentage of industry funding at the university may positively influence invention disclosure submission by 9%, and startup activity by 3.32%, all else equal. This finding confirms findings from previous studies on the influence of industry sponsored research on invention disclosure receipt (Friedman & Silberman, 2003), on licensing activities (Chukumba & Jensen, 2005), and on startup formation (Powers & McDougall, 2005a; O'Shea, et al., 2005; Jensen & Jones, 2011). The finding for industry funding from this current study and others suggests that university-industry interactions may have a positive influence upon a university's entrepreneurial efforts and culture of support for faculty collaborations with industry partners.

TLO experience is controlled for its number of years in existence, and is found to be positive and strongly significant for invention disclosure receipt ($p<0.001$), each additional year potentially increasing disclosure activity by 3.12%, suggesting older TLOs may be more experienced and effective at obtaining invention disclosures than TLOs with less experience. Older TLOs, who have more experience working with faculty members for commercializing their inventions, may have a positive influence due to previous successes (Chukumba & Jensen, 2005; Thursby & Thursby, 2007). The significance indicated for the age of the TLO may also reflect universities with more time cultivating cultural acceptance towards faculty entrepreneurship rather than direct engagement of the TLO. The age of the TLO is not shown to have a significant relationship with either licensing activity or startup formation. This supports findings by some (Markman, 2005a; Markman, et al., 2009), that the age of the TLO is not significantly related to licensing revenues. However, this finding of non-significance is opposite those of other studies (Chukumba & Jensen, 2005; Powers & McDougall 2005a & 2005b; Jensen & Jones, 2011), that TLO experience gained over time has a positive influence upon startup activity. As TLO age has a somewhat positive correlation with both research

expenditures (>0.48) and licensing staff (>0.6), the ratio of licensing staff to research expenditures may have removed some multicollinearity.

Previous technology transfer activity activities and historical pipeline inputs show positive and significant relationships with commercialization outcomes. The elasticity estimates on the logged average historical metrics from 2003-2006 indicate that prior commercialization activity can have a significant influence upon subsequent activity. Each estimate for the pipeline inputs is positive and strongly significant ($p<0.001$). The elasticity estimate for prior invention disclosure (0.858) for licensing activity suggests a high positive relationship between invention disclosure in 2003-2006 and subsequent licensing efforts; not one-to-one, but a positive influence nonetheless. The elasticity estimate for prior invention disclosure (0.658) for startup formation indicates a positive relationship between invention disclosure receipt in 2003-2006 and subsequent startup formation, supporting findings by Jensen & Jones (2011) that invention disclosures are a critical input for university startup formation. The elasticity coefficient for previous licensing efforts in the startup regression indicates a negative relationship between previous licensing efforts and subsequent startup formation (-0.234%, $p<0.05$), the estimate indicating a 1% increase in prior licensing activities may reduce subsequent startup formation by 0.23%. This suggests university TLOs who have had success in the past with licensing efforts may be strategically focused upon licensing rather than startup formation. This finding provides support for Chukumba & Jensen's (2005) suggestion that university TLOs who have success in past licensing activity may be locked into that activity, and not be focused upon startup formation; potentially using that commercialization path as a last resort. This also provides some additional support for the finding by Bercovitz, et al., (2001), that equity use as a licensing mechanism to startups is diminished with higher prior licensing activity.

As seen above in table 4.7 and figure 4.4, the two most prevalent combinations of organizational structure and educational background of TLO director in this study are TLOs reporting to an office of research, with either a TLO director with a PhD, or a TLO director with an MBA educational background. When these two most prevalent structures are compared with the remaining

structures, only one, the TLO reporting to an office of research with an MBA directing the office, is shown to be more effective than the remaining 15 structures at obtaining invention disclosures. No significance is indicated for either licensing activity or startup formation between these two common structures and the others. Results from the comparison of the TLO reporting to an office of research with an MBA director are included below (table 4.14). The combination of the two characteristics together does not significantly alter the estimates on the other variables in the regression, however the significance of industry sponsored research levels on startup formation is dropped.

Table 4.14 Regression Results, Comparing TLOs Reporting to an Office of Research with an MBA Director to All other TLO Arrangements

	(1) Invention Disclosures		(2) Licenses		(3) Startups	
Report to Research & Director MBA	0.450*	56.83%	-0.242	-21.49%	0.0760	7.90%
	(0.215)		(0.230)		(0.170)	
Director tenure	-0.0179	-1.77%	0.0117	1.18%	-0.0132	-1.31%
	(0.0169)		(0.0157)		(0.0134)	
Private	0.452*	57.15%	-0.274+	-23.97%	-0.158	-14.62%
	(0.176)		(0.146)		(0.122)	
Medical School	0.564*	75.77%	-0.259	-22.82%	0.122	12.98%
	(0.213)		(0.230)		(0.111)	
Law School	0.364*	43.91%	0.0268	2.72%	0.229*	25.73%
	(0.160)		(0.172)		(0.105)	
Licensing Staff/ M$ Research Funding	-11.17*	-1.00%	-7.829	-1.00%	-3.161	-0.96%
	(4.885)		(5.311)		(2.230)	
Industry Research %	2.309**	9.06%	-0.822	-0.56%	1.184	2.27%
	(0.851)		(0.942)		(0.822)	
TLO Age	0.0294***	2.98%	-0.00418	-0.42%	0.00728+	0.73%
	(0.00652)		(0.00577)		(0.00420)	
Log Avg Inv. Disc.T1			0.914***	1.49%	0.657***	0.93%
			(0.0943)		(0.115)	
Log Avg Licenses T1					-0.224+	-0.20%
					(0.113)	
_cons	3.218***		-0.542		-1.154***	
	(0.397)		(0.486)		(0.295)	
N	76		75		75	
R^2	0.501		0.658		0.637	
adj. R^2	0.441		0.611		0.580	
F	12.12		31.96		12.84	

Standard errors in parentheses
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Discussion

This paper initiates a line of inquiry in response to the call for more in-depth evaluation of TLO capabilities, structure, educational skillsets, and activities that can influence the technology transfer process and its outcomes (O'Shea, et al., 2008; Lockett & Wright, 2005). Organizational decision making and financial characteristics of university TLOs are shown to influence technology transfer activities (Bercovitz, et al., 2001; Markman, et al., 2005b; Markman, et al., 2009; Feldman & Bercovitz, 2010). This project contributes an evaluation of the TLO reporting structure and educational skillsets of the TLO director and their influence upon technology transfer metrics. Considerable diversity exists across universities in TLO organization (Siegel, et al., 2003), and in coordination levels with other university units (Feldman & Bercovitz, 2010). The organizational structure alignment of the TLO and the skillsets of its staff members may provide opportunities and resources via collaboration and coordination efforts with parties internal and external to the university. We find 16 different potential combinations, with the two primary structures being TLOs organized under an office of research with either a PhD director or an MBA director. In comparison with others, we find the TLO organized under the office of research with an MBA director to be more effective at obtaining invention disclosures from academic researchers, but not significantly different in either of the outcomes. The other most commonly organized TLO, reporting to the office of research with a PhD director, did not have any significant difference in any of the three metrics when compared to other TLOs.

The findings on the educational background of the TLO director suggest commercialization skills taught through an MBA program may be beneficial in obtaining invention disclosures, licensing efforts, and forming university startups. Commercialization skills of the TLO director developed through experience may also facilitate startup formation; but is quite difficult to measure in practice. The current study provides some evidence of a positive relationship between business and commercialization skills taught through an MBA educational degree and increased disclosure and startup activity when compared to TLO directors with a PhD, and in licensing efforts when compared

to a TLO director with a JD. Our findings from this analysis provide some support for prior studies which suggest universities invest in hiring TLO licensing professionals with advanced business skills (Markman, et al., 2009) or in educational opportunities or programs designed to increase the broad-based commercialization skillsets of the TLO (Siegel, et al., 2007; Litan & Cook-Deegan, 2011). The finding of a negative between TLO directors with JDs and licensing activity is considerable in this analysis, indicating a TLO director with a JD may be less effective than TLO directors with all other educational backgrounds in licensing university inventions. This finding would indicate that while legal knowledge is an important element for the technology transfer process in intellectual property protection and contractual language, legal wrangling in negotiation practices may limit successful licensing opportunities.

Results from a number of (but not all) previous studies on university institutional and historical characteristics are supported by this study. The presence of a law school has a positive relationship with both invention disclosure and startup activity. The finding of a positive relationship with startup activity is consistent with and supports previous finding by Feldman & Bercovitz (2010), the positive relationship with invention disclosures suggests a relationship that may benefit from further exploration. The findings for private schools suggest private institutions may be effective in obtaining invention disclosures from research faculty, but less effective at licensing and startup formation than public institutions. The presence of medical school is shown to be a positive influence upon invention disclosure receipt, but not for licensing or startup efforts, suggesting medical schools may have high rates of invention disclosures, but those inventions may not necessarily turn into commercial opportunities at any higher rate than disclosures from other departments. The finding for medical schools confirms those of Kim (2013); medical schools had no significant influence on the licensing activities of 90 universities between 1999 and 2007. The influence of the medical school on commercialization outcomes may have lessened as other institutions increase their commitment to technology transfer. Bulut & Moschini (2009) find the combination of a medical school and a private university has a positive relationship with licensing revenues, suggesting this combination of

characteristics may have a larger pipeline of disclosures with which to work, and may be able to negotiate a higher rate of return with successful licensing efforts.

Corroborating previous studies, this analysis finds the effects of experience and history have a strong influence upon an institutions' ability to successfully commercialize academic innovations (O'Shea, et al., 2005). Prior TLO invention disclosure history is shown to have a strong influence upon subsequent licensing and successful startup formation, as noted in previous studies (Friedman & Silberman, 2003; Chukumba & Jensen, 2005; O'Shea, et al., 2005; DiGregorio & Shane, 2003); confirming the criticality of invention disclosure for the technology transfer process. Prior licensing activity has a negative relationship with subsequent licensing efforts, suggesting universities may be locked into licensing from past successful efforts. The findings from this analysis of TLO characteristics suggest that the technology transfer activities of US research universities continue to evolve and expand, and correspondingly the influence of university characteristics on commercialization outcomes will continue to change.

Limitations and Future Research

This study is an initial inquiry into the impact of TLO organizational structure and TLO director's educational skills on specific university technology transfer commercialization metrics. This evaluation leverages heterogeneity in TLO reporting structure and TLO director educational background across 76 US universities in an attempt to highlight characteristics that influence commercialization outcomes. While this study has some limitations, it contributes an empirical analysis to the discussion of how heterogeneity in TLO characteristics across universities helps to explain differences in commercialization outcomes. This analysis indicates a correlation between specific TLO characteristics and technology commercialization outcomes, and provides motivation for further exploration of university infrastructure and capabilities of the TLO over time.

Limitations in this current study include the small number of TLOs reporting to multiple offices in this analysis; 6 out of the 76 universities included in this study are organized under this

reporting relationship. Further analysis with additional TLOs under multiple reporting structures may help to properly evaluate this structure's influence upon commercialization outcomes. Some care should be taken with interpretations of this analysis, as relationships between organizational structures may be contingent upon the type of institution, its size, research funding levels, and the existence of various schools within the institution. The sample evaluated in this analysis is from 76 research universities, not an extremely large set to be able to effectively compare the 16 different possible organizational structures to each other. There may also be endogeneity in the model in that the reporting structure may have evolved at the university in response to the culture, history, and needs of the institution, and hiring of the TLO director may have been influenced by the same characteristics. There may be a causal loop between organizational characteristics of the TLO and technology commercialization metrics. For example, universities more highly engaged in entrepreneurial activities in the past may have purposely aligned their office with an economic or business development function to facilitate those activities. Therefore, while a relationship is indicated between some of the different organizational structures of the TLO and commercialization outcomes, no causal direction can be inferred.

As indicated in the technology transfer processes in figure 4.1, a variety of skills and experience are needed to facilitate the different stages of the technology transfer process and commercialization outcomes. The last educational degree of the TLO director is a rough proxy for knowledge and skills of the TLO director, however it does not enable quantification of broad-based commercialization skillsets that are developed outside of the educational experience, and may not capture the full set of skillsets of these individuals. Accordingly, estimates need to be interpreted with some caution. They do provide a starting point for a conversation regarding the breadth and depth of skills required in technology commercialization activities. Further evaluation is needed to determine if there are better proxies for TLO director educational knowledge base, commercialization experience, and on the job skill development. A more thorough and detailed analysis can help to evaluate the many different types of skills needed in academic technology commercialization

activities and to discover the full set of educational, experience, skills and other knowledge characteristics needed for the technology transfer process. Further analysis is needed to explore the negative relationship between licensing activity and TLO directors with a JD, particularly to evaluate the relationship between this educational background and revenues received from successful licensing efforts. The estimate on the licensing staff/research funding ratio suggests that adding an additional staff member may potentially have a negative influence if research funding is not also expanding. This finding calls for further analysis to determine the best ratio of licensing staff per research funding levels before reaching levels of diminishing returns.

Also missing from this current study are measures of faculty quality, as previous studies find quality of institutional faculty influences the number and quality of invention disclosures received by the TLO (Thursby & Kemp, 2002; Friedman & Silberman, 2003; O'Shea, et al., 2005; Powers & McDougall, 2005a; Bercovitz & Feldman, 2008; Markman, et al., 2009), as well as subsequent commercialization activities (DiGregorio & Shane, 2003; Powers & McDougall, 2005b; Jensen & Jones, 2011). Faculty quality indicators were not readily available for this analysis; subsequent research may benefit from including such a measure due to the strong influence faculty quality can have on invention disclosure submission, required for any subsequent commercialization efforts (Bercovitz & Feldman, 2008).

Contribution of Study

This study advances the existing body of literature regarding characteristics of entrepreneurial universities and the organizational structures of technology licensing offices, contributing to research analyzing university and TLO characteristics and capabilities. Rothaermel, Agung, and Jiang (2007), in their thorough review of academic entrepreneurship studies note a common thread among the conclusions of studies in their review: a great need for barrier elimination (such as lack of appropriate commercialization skills in the TLO) in the technology transfer process to increase TLO efficiency and effectiveness. The current analysis of organizational structure and educational skillsets within the

TLO provides additional insight into characteristics that can be strategically aligned to reduce potential barriers to technology transfer.

University Implications

Results from this study provides key information to university leaders regarding the strategic implementation of their technology transfer processes, and how internal organizational structure and skillset alignment in the TLO can facilitate technology transfer outcomes. The information provided by this study highlights the importance of the role that organizational structure and various educational skillsets available to the TLO play in supporting university technology commercialization goals. Universities may benefit from establishing a strategic approach to the commercialization of academic inventions as suggested by Siegel, et al., (2007), addressing commercialization skill deficiencies in the TLO and supporting organizational structures that can more readily access technology commercialization resources. Choices of commercialization goals and priorities, allocation of resources, organizational structure, skill development in the TLO, and policies to incentivize faculty disclosure of inventions fall to institutional leadership (Siegel & Phan, 2005). University leaders and TLOs make strategic decisions regarding commercialization pathways of inventions (Rothaermel, et al., 2007); and alignment of organizational configurations and other characteristics under the control of the university may increase potential for success. University leaders may wish to focus efforts on specific technology transfer outcomes, and developing an understanding of the characteristics that influence those strategic choices can be beneficial. Institutional leaders can ensure appropriate policies are in place to create or enhance a culture of innovation and entrepreneurship, and to support and incentivize invention disclosure from university researchers (Siegel, et al., 2007; ipHandbook, 2012). Incentive policies can increase the likelihood of inventions resulting from academic research activities to be disclosed to the TLO; increasing the critical input into the commercialization pipeline and opportunities for success technology transfer (Siegel, et al., 2007).

Skillsets within the TLO are important and can provide support for the various steps along the technology transfer process. This study indicates that commercialization skills associated with an MBA degree may have a positive influence upon invention disclosures and startup formation when compared to a TLO director with a PhD, and a positive influence upon licensing activities when compared to a TLO director with a JD. This finding supports previous suggestions universities invest in commercialization training for their TLOs and entrepreneurial faculty (Siegel, et al., 2007). While legal expertise is quite important for intellectual property protection, evaluating federal, state and local laws, and verifying legalities of terms in agreements (O'Connor, et al., 2010), increased legal wrangling in licensing negotiations may have a negative influence as suggested by Siegel, et al. (2003), raising important implications for university administrators in determine appropriate alignment of skills to facilitate the universities strategic goals for successful transfer of university inventions to industry. "Success begets success," a history of achievement in technology transfer can increase faculty awareness and have an impact upon the university's entrepreneurial culture (Owen-Smith & Powell, 2001, p 111). Aligning organizational structure and educational skillsets within the university environment to facilitate technology transfer activities can provide increased opportunities for successful commercialization of university inventions.

Policy Implications

This study also provides timely data and information for legislators who view university entrepreneurship and technology transfer as an important form of economic development across the US. The information provided in this and other recent studies on university TLO commercialization activities is important to consider as US research universities address increased federal and state expectations for commercialization of research results and economic development impact. This line of inquiry will be helpful for policy advocates to consider as initiatives designed to enhance university technology commercialization outcomes are being reviewed by federal committees (specifically the Science, Space & Technology Committee), and draft legislation is being discussed to

support innovative approaches to academic technology commercialization efforts (H.R. 2981, & H.R.714).[29]

Results from this research improve the understanding of how university TLO organizational structures and educational skillsets influence certain academic technology commercialization activities and outcomes. These unique reporting structures and educational characteristics can affect the coordination efforts and focus of the TLO within the university and its environment, as well as the technology transfer process itself, which can in turn influence the eventual commercialization of academic inventions. This research provides valuable information for university leaders and interested policy makers evaluating institutional goal and capability alignment for the organization of university technology licensing operations.

[29]Subcommittee on Research and Technology–Improving Technology Transfer at Universities, Research Institutes and National Laboratories: http://science.house.gov/hearing/subcommittee-research-and-technology-improving-technology-transfer-universities-research

Chapter 5. Discussion and Policy Implications

Introduction

A changing economic environment, increasing budget constraints for research activities, and growing expectations regarding the university's role in economic development has prompted a reevaluation of the university technology transfer process and its outcomes (Leigh & Teece, 2013). US research universities work to enhance their technology commercialization efforts while also maintaining the integrity of the original educational and basic research missions of the research university (Breznitz & Feldman, 2012). Success in technology commercialization efforts depends upon many factors, including regional characteristics, entrepreneurial culture, university leadership, the strategic focus of the university on technology commercialization, the availability of investment funding, as well as the organization and capabilities of the TLO function within the university (Leih & Teece, 2013). When leaders of US research universities contemplate the potential for their institution to have an impact upon their economic development through their technology transfer efforts, characteristics and attributes across all of these areas are important to consider.

The three projects contained within this dissertation project provide information on a variety of university and TLO characteristics that are shown to have an influence on the academic technology transfer process and that may also influence any potential collaborative efforts for technology commercialization consortia. Universities can have an impact upon regional economic development through a variety of channels, including new business creation, collaborative engagement with industry research, and by increasing the transfer and commercialization of academic inventions from the university to industry partners (Audretsch, 2013). These research projects address issues relevant to these channels. The first, a literature review, synthesizes findings from prior studies on characteristics related to growth in technology transfer efforts at US research universities.

Characteristics of universities and TLOs are evaluated for how they may influence invention disclosure from faculty; licensing activities, revenue generation, startup formation, and use of equity. The influence of regional characteristics on these activities is also considered. Gaps in analysis of certain university and TLO characteristics are identified for further review. The second project comprises a case study evaluation of an early stage licensing consortium in North Carolina's Research Triangle Park; TULCO. This case study analysis provides background and history of the consortium, its day to day operations, and the consortium's influence upon patenting and licensing activities of the three universities, and of circumstances leading to TULCO's eventual demise. The case study on TULCO provides some context for current conversations at the national and regional policy levels regarding potential academic technology licensing consortia. The third project provides an analysis of specific TLO organizational reporting structures, educational background and job tenure of the TLO director, and how these characteristics factor into the technology transfer process. The empirical study evaluates data from 76 US research universities to explore relationships between these characteristics on invention disclosure receipt, licensing and startup formation, finding that differences in configurations of TLOs can influence the technology transfer process and its outcomes. These findings indicate there may be some potential for characteristic alignment in support of certain activities along the technology transfer process and its outcomes.

Literature Review

Selected studies are evaluated to better define university characteristics that may help to explain heterogeneity across US research universities in technology commercialization outcomes. US universities have become more efficient in technology commercialization efforts, but see year to year volatility (Kim, 2013), illustrating the dynamic nature and pipeline aspect of the academic technology transfer process and its outcomes. Faculty quality and higher research funding levels are found to be strongly positively correlated with invention disclosures, determined by several studies to be critical inputs into the technology commercialization process (O'Shea, et al., 2005; Friedman & Silberman,

2003; Markman, et al., 2005). Smaller universities with less available resources to use towards technology licensing may be applying those resources more efficiently than larger universities (Thursby & Kemp, 2002). Universities with larger TLOs are more efficient at licensing and startup activity compared to those with smaller offices (Siegel, et. al, 2003 & 2008), but there may be some diminishing returns in efficiency with growth in the TLO (Thursby & Thursby, 2002). Older TLOs are generally associated with higher licensing revenues, which may be a function of successful historical licensing efforts (Siegel, et al., 2008). Faculty quality and engagement with the commercialization process are quite important at the beginning of commercialization efforts, as are the universities degree of support for entrepreneurial activities of faculty (Markman, et al., 2005a; Powers & McDougall, 2005b). The type of research and the level of funding also have an impact upon technology transfer; institutions with high levels of research funding have higher levels of invention disclosure to the TLO (Friedman & Silberman, 2003), and have higher licensing activities and licensing revenues (Thursby & Thursby, 2007; Bulut & Moschini, 2009; Chukumba & Jensen, 2005). Federal and industry funding levels also have a positive factor in startup formation, particularly industry funding levels (Markman, et al., 2004; Powers & McDougall, 2005a; O'Shea, et al., 2005; Chukumba & Jensen, 2005; Jensen & Jones, 2011).The universities policy orientation and support of entrepreneurial faculty can have a significant impact upon a university's success in technology commercialization; universities supportive of entrepreneurial faculty and of the TLO have a positive influence on growth in invention disclosures (Thursby & Kemp, 2002; Thursby & Thursby, 2002), however incentive policies with higher rates of royalty sharing with inventors may stifle startup formation (DiGregorio & Shane, 2003; Markman, et al., 2004; Markman, et al., 2009).

Previous experience with successful technology commercialization, startup formation, and use of equity is an important factor in subsequent successes (Digregorio & Shane, 2003; O'Shea, et al., 2005). Institutions utilizing equity in licensing to university startups are typically larger research institutions, have strong support from institutional leadership, and correspondingly supportive entrepreneurial cultures (Bray & Lee, 2000; Smilor & Mathews, 2004). Feldman, et al., (2002) also

find structural characteristics such as a presence of a medical school and prestige (i.e. research universities with a Carnegie classification) increased the likelihood of use of equity in licensing mechanisms. Taking equity in a startup may provide additional credibility, possibly attracting additional investment (Feldman, et al., 2002). This licensing mechanism aligns the interests of both the startup and the university towards long-term success in getting the academic innovation into the commercial sector (Bray & Lee, 2000).However taking an ownership portion in a new venture is also quite risky, as often there is no interest expressed by existing industry either because the invention isn't considered profitable or no market currently exists (Feldman, et al., 2002), suggesting university startups may face additional hurdles in commercialization efforts. TLO structures also have an influence upon technology commercialization efforts. Traditionally structured TLOs (organized as an integral unit of the university) and TLOs with low autonomy and authority in decision making have lower levels of licensing revenues and startup formation, while TLOs organized under a for-profit structure have higher rates of startups and use of equity (Markman, et al., 2005a, Markman, et al., 2009), and TLOs expected to be self-funded are less likely to utilize equity (Feldman, et al., 2002).

Policy considerations for universities are many from this literature review. University characteristics including supportive policies and an entrepreneurial orientation of the university, faculty quality, research funding, amount of industry funding, experience, and business capabilities of the TLO are all points to consider for short and long term success of university technology commercialization efforts. For universities without significant previous history and success in licensing university inventions, there may be characteristics and attributes of the university and the TLO that can be evaluated and modified to influence the probability of success and establish a track record. Some characteristics may be influenced by university leadership, including hiring quality research faculty; supporting increased research partnerships with industry; reviewing and updating incentive policies to support entrepreneurial efforts. Commercialization skills and business networks of the TLO can support licensing and startup efforts (Markman, et al., 2004), however the lack of these skills is noted by several as potential barriers to technology transfer activities, extending the

length of time to finding licensees and forming startups (Siegel, Waldman & Link, 2003; Markamn, et al., 2005a; Markman et al., 2009; Litan & Cook-Deegan, 2011). Hiring or providing appropriate commercialization training to the licensing staff of the TLO may help address some of these barriers. External characteristics such as venture capital availability and the concentration of related industry can be taken into consideration in developing policies regarding licensing, startup formation and the utilization of equity in licensing to startups.

Collaborative Technology Transfer

The case study of an early technology licensing consortium provides lessons learned from the efforts of Duke University, North Carolina State University and The University of North Carolina at Chapel Hill to collaborate on technology commercialization and licensing. Analysis of this early stage consortium suggests pooling resources through a single licensing consortium increased effectiveness in technology commercialization efforts at the individual universities. This case study provides compelling evidence in support of increased technology licensing activities from the three triangle universities through combined efforts and shared subject domain expertise in the licensing staff members of TULCO. Combining licensing efforts through a single entity allowed more inventions to reach the commercial market than each of the universities could do on their own, as they each had little internal infrastructure and no (or few) established processes for technology commercialization. Successes and pitfalls from the early consortium are analyzed, as well as trends in licensing and patenting activities for the three universities during and immediately following the consortium. This consortium helped to address a burgeoning need and desire of regional policy makers and university leadership to move academic inventions forward by engaging with and licensing these inventions to industry. Once established, TULCO was quite effective in licensing efforts; however the growing needs of the three universities and their entrepreneurial faculty outpaced the capacity of the consortium, leading to internal infrastructure development at each of the universities to meet the needs TULCO was unable to fill. Findings from this project are timely and are applicable to

institutions considering partnering with others to more effectively and efficiently license and commercialize academic based research results.

In particular, the policy implications of the TULCO experience for the University of North Carolina system may be particularly informative. Currently, the two large research universities of the system, the University of North Carolina at Chapel Hill, and North Carolina State University in Raleigh lead technology commercialization and startup activity within the 17 campus UNC system, and have well-established infrastructures for marketing and commercialization efforts (AUTM, STATT, 2012). A group of smaller universities within the North Carolina system, including UNC Charlotte, East Carolina University, UNC Greensboro, North Carolina Agricultural and Technical State University, and to some extent, UNC Wilmington have established small technology licensing offices to help move commercially viable innovations forward to the market. The remaining 10 institutions across the state (Appalachian State University, Elizabeth City State University, Fayetteville State University, North Carolina Central University, UNC Asheville, UNC Pembroke, UNC School of the Arts, Western Carolina University, Winston-Salem State University, and the North Carolina School of Science and Mathematics) are without any formalized marketing or commercialization mechanisms on their campuses; as low level research campuses, there may not be a budgetary justification for the establishment of an on-site technology commercialization resource. A technology licensing consortium for the UNC system schools would provide a mechanism for those institutions currently without any technology commercialization capabilities to be able to access resources not currently available to their campuses. Universities that now have on-campus technology commercialization capabilities could leverage any resources provided through a system-wide licensing consortium to enhance existing internal capabilities for marketing and commercialization efforts, thereby expanding existing domain expertise and industry networks. As entrepreneurial cultures become more commonly accepted in university environments, and research activities continue to grow, universities with active engagement in research activities and industry collaboration

may eventually require an on-site TLO to develop relationships and provide in-person support to faculty researchers and other innovators across their respective campuses.

Organizational Characteristics and Technology Transfer Performance

Institutional, organizational, and TLO characteristics are shown in several previous studies to have an impact on technology commercialization outcomes. Organizational reporting structures of the university TLO can facilitate technology transfer outcomes through their coordination and integration with other functions internal to the university as well as resources external to the campus environment (Bercovitz, et al., 2001; Feldman & Bercovitz, 2010; Markman, et al. 2009). The empirical analysis in Chapter 4 of the reporting structure of the TLO, educational background and tenure of the TLO director find these characteristics can factor into the university technology transfer process and its outcomes.

Positive relationships are found between TLOs reporting to multiple functions within the university and increased licensing activities; and between TLOs reporting to an economic/business development function or the university leader and increased startup formation when compared to TLOs reporting to the office of research. The strength of these relationships and the effect sizes on these alternative TLO reporting structures in comparison to the most common reporting structure (office of research) support the initial premise that different TLO reporting structures may have an impact on certain technology transfer outcomes over others. The increased coordination efforts of TLOs reporting to multiple functions within the university may provide an expanded network from which to develop industry contacts for successful licensing. TLOs reporting to the university leader or to an economic/business development function may be coordinating efforts with external resources, providing access to an expanded industry network and investment funding in the region, potentially influencing startup formation as suggested by Markman, et al., (2009, p.636).

The educational background of the TLO director most aligned with the calls for increased commercialization skills (MBA) is positively related with invention disclosure receipt and startup

activity when compared with TLO directors with PhD educational backgrounds. TLO directors with MBAs are also more effective in licensing when compared with TLO directors with legal (JD) educational backgrounds. The results from this study suggest TLO directors with legal (JD) degrees are less effective in licensing activities when compared to TLO directors with all other educational backgrounds, potentially due to risk adversity and legal wrangling as suggested by others (Siegel, et al., 2003). The intersection of educational skills and experience developed beyond educational degrees remains an open question for further analysis. From a policy perspective, the relationship between TLO directors with a legal degree and lowered licensing activity may be worth noting as university administrators work to find ways to remove barriers for effective technology commercialization. An evaluation of those directors with MBA degrees who are effective in obtaining invention disclosures and licensing academic inventions from their university may provide some additional knowledge and indications of the types of skillsets and experience that enable successful efforts.

Policy implications are such that universities who may be interested in emphasizing one particular commercialization path over others may consider the structural alignment of their internal TLO function to ensure maximum coordination and integration efforts with other university units that can effectively support those strategic commercial pathways, whether for licensing directly to industry or forming startups. If a general increase in each type of technology commercialization is the objective, ensuring appropriate resources are available to the TLO as well as capabilities of coordination with other units and entities external to the university that can support both licensing and university startup efforts. Building relationships with other university units increase opportunities for effective integration with the campus community, establishing relationships with industry partners for research and prospective licensing, and capabilities of the TLO to leverage external resources in support of the technology transfer process can all have a positive influence on university technology commercialization efforts.

Conclusion

Technology commercialization at research universities necessarily occurs in environments influenced by regional attributes (geographic, industry and entrepreneurial characteristics, investment availability), policies and regulations (local, state and national laws, conflict of interest policies), as well as characteristics of the research university itself, and of its TLO. Universities evaluating organizational structure, skills and capabilities for potential alignment to facilitate the technology transfer process, whether licensing activities, startup formation, or both commercialization paths, will likely find this analysis of characteristics of the university and TLO on the technology transfer process helpful. Determining and using the best alignment of organizational structures and capabilities may increase a TLO's effectiveness in transferring academic inventions to the market through coordination with other university functions strategically aligned with the focus of the TLO. As summarized in prior work, the characteristics under control of university leadership that can influence a culture of entrepreneurship and potentially increase the university's regional economic development impact are many. Supporting increased research partnerships with industry can also contribute to an entrepreneurial culture, and may stimulate the formation of startups from the university, as found in the current empirical analysis and in prior studies (Chukumba & Jensen, 2005; Powers & McDougall, 2005).

Licensing consortia may be fruitful for research universities with smaller levels of research funding and that may not have the infrastructure or funding for the development of a full functioning office. Consortia among research universities to help move publicly funded academic innovations are being discussed at the national policy level, and the case study analysis provides some guidance from the history of an early stage consortium designed to increase licensing and commercialization efforts among the three triangle universities in North Carolina's Research Triangle Park. Combining resources with other institutions can provide opportunities to leverage tools more effectively (market research reports, data engines and other services), expand subject matter expertise and provide access to expanded industry networks that might not be accessible when universities are working alone.

Geographic limitations may have been broken down somewhat through advanced means of communication, so may not be as important today as it was during the time of TULCO, however successful relationships will be cultivated through good communication among the members of any technology licensing consortia, among the member institutions, the inventors, and industry networks. The promises and pitfalls from TULCO's early efforts can provide guidance for institutions considering forming partnerships for technology commercialization efforts.

TLO organizational characteristics, including financial structures (Markman, 2005a), organizational form (Feldman et al,. 2001), level of autonomy (Markman, et al., 2009), as well as the TLOs reporting relationship can all factor into a TLO's effectiveness in working with faculty to increase invention disclosure submission, and the degree to which they are able to negotiate licenses with industry and support university startups. A lack of commercialization skills within the TLO has been held up as a potential barrier to technology licensing and startup activity, with additional suggestions that universities hire or provide appropriate training to increase or enhance business development and commercialization skillsets of the TLO (Smilor & Matthews, 2003; Siegel, et al., 2003; Markman, et al., 2004; Markman, et al., 2009), and of entrepreneurial faculty (Siegel, 2012). The empirical study in this dissertation begins to analyze how educational background of the TLO director can facilitate or hamper technology commercialization activities. Some alignment with educational backgrounds can be done to remove potential barriers; however the characteristics of a TLO director and staff members that facilitate successful licensing and startup formation are likely to be beyond pure educational background, but rather a combination of education, skills, experience, and possibly luck. Educational degrees of the TLO director are a rough proxy for knowledge and skillsets, and may be missing other factors related to knowledge and skills gained through experience or other mechanisms. Further research and evaluation of commercialization skillsets of TLO licensing staff members may help determine the variety of skills that may lie in the set of 'broad based commercialization skills' considered lacking in many university TLOs.

The empirical evaluation adds to previous academic studies by evaluating possible correlations and relationships between specific TLO characteristics (reporting structure of the TLO and the degree of the TLO director) with an institution's effectiveness in commercializing academic inventions through licensing and startup formation. This project contributes to the knowledge base and understanding upon which academic technology transfer activities are evaluated for university administrators, regional and national legislators and those external to the research university environment, providing insight for the decision making processes of US research universities as they evaluate the effectiveness of their entrepreneurial support and technology commercialization efforts.

General findings from these research projects will be noteworthy to university administrators, boards, and trustees who wish to facilitate technology transfer and entrepreneurial activities of their research faculty. The information provided through each of the research papers included in this dissertation project delivers a collection of information on university attributes and TLO characteristics that may also be of interest to and utilized by funding agencies and legislators involved in policy development for US research universities. University administrators focused upon a particular strategic direction for technology commercialization efforts are provided with information regarding characteristics that may influence that strategic direction, and can make changes accordingly to those characteristics over which they have some control. University administrators, policy makers and government agencies who fund research being conducted at US research universities will find the results of these studies informative as universities and TLOs respond to increased regional and national expectations for economic development impact.

APPENDIX A TULCO DISCUSSION GUIDE

Discussion Guide for A Case Study and Historical Analysis:
Triangle University Licensing Consortium (TULCO)

Research study conducted by Lisa A. Goble and Maryann Feldman
Department of Public Policy, UNC-Chapel Hill

1. Please would you describe for me your role as a staff member, inventor or licensee? What time period(s)?

2. I understand the primary responsibility of this partnership was to market and license the inventions, and develop industry-sponsored research collaborations to further develop those inventions. Do you think TULCO achieved those primary objectives? Why or why not?

3. Prior to TULCO there was little patenting and licensing at the 3 Universities? Do you feel that the consortium was successful in: Encouraging patenting? Licensing innovations created at the universities? Creating more industry sponsored research?

4. How did the 3 Universities (Duke, UNC and NCSU) work together?

    a. Any instances of collaboration between the 3 universities?

    b. Were there rivalries?

    c. Do you feel that the institutions working together realized efficiencies or gains in cooperation? Why/why not?

5. There was probably a tension between providing quality service to the faculty inventors and focusing on other objectives. What was TULCO's priority?

6. Why was TULCO disbanded? What led to its demise? What were the circumstances leading up to the disbanding of TULCO? Were there specific reasons stated?

7. Would you recommend this type of consortium model for other institutions?

8. Are there any additional comments you'd like to add to what we've already discussed, or can you suggest additional questions that should be included?

9. Are there other individuals that you can recommend I speak to whose knowledge can contribute to this preliminary analysis?

APPENDIX B TULCO FIGURES

University Issued Patents, 1980-2003

Figure 3.4 University Issued Patents by Application Year, 1980-1987

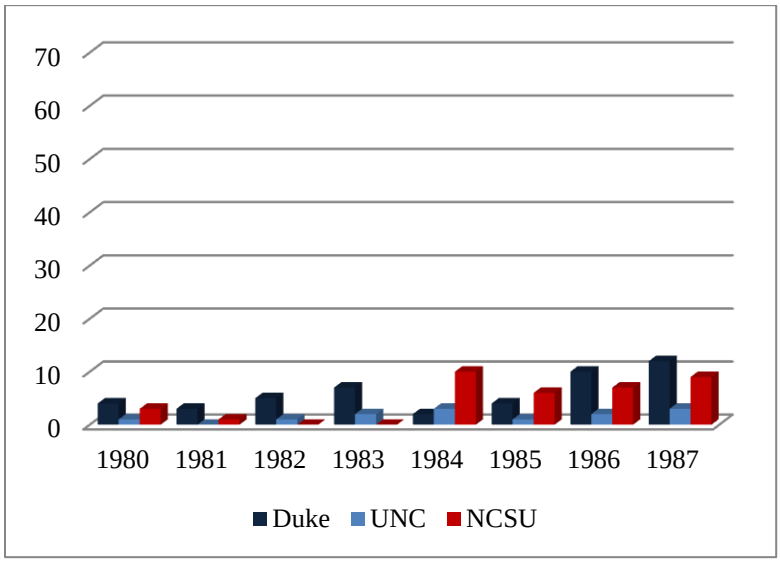


Figure 3.5 University Issued Patents by Application Year, 1988-1995

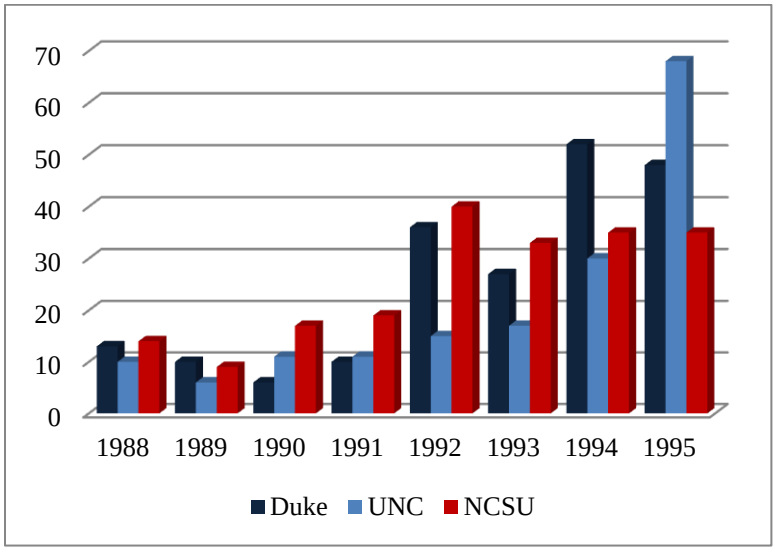
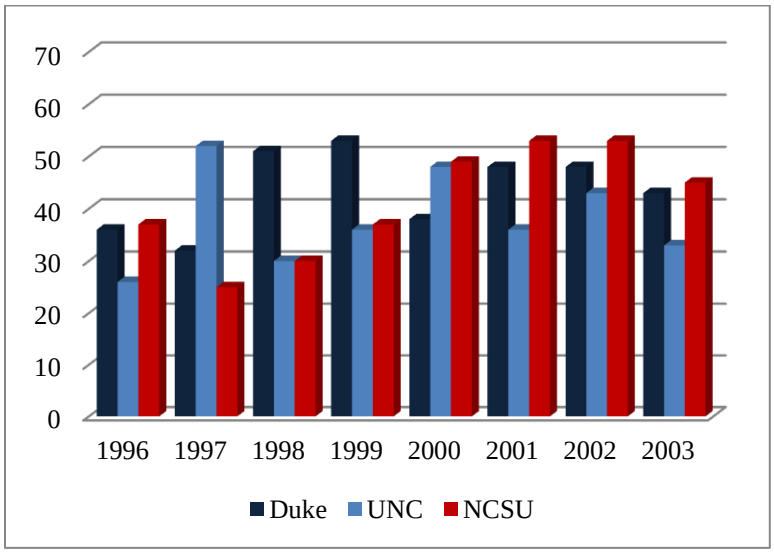


Figure 3.6 University Issued Patents by Application Year, 1996-2003



APPENDIX C ADDITIONAL TABLES AND FIGURES

Table 4.15 Regression Results, Economic/Business Dev. Reporting & MBA as Comparison

OLS (08-10)	(1) Invention Disclosures		(2) Licenses		(3) Startups	
Research Office	0.394	48.29%	0.0288	2.92%	-0.257+	**-22.66%**
	(0.329)		(0.226)		(0.143)	
Institutional Leader	0.565	75.94%	0.215	23.99%	0.0526	5.40%
	(0.414)		(0.243)		(0.159)	
Multiple Offices	0.599	82.03%	0.693+	**99.97%**	-0.321	-27.46%
	(0.420)		(0.396)		(0.247)	
Director PhD	-0.451*	**-36.30%**	-0.0380	-3.73%	-0.295+	**-25.55%**
	(0.216)		(0.209)		(0.168)	
Director JD	-0.508	-39.83%	-0.493*	**-38.92%**	-0.178	-16.31%
	(0.307)		(0.226)		(0.208)	
Director BS	-0.367	-30.72%	0.321	37.85%	-0.0561	-5.46%
	(0.294)		(0.274)		(0.191)	
Director tenure	-0.0237	-2.34%	-0.0103	-1.02%	-0.0115	-1.14%
	(0.0185)		(0.0147)		(0.0127)	
Private	0.393*	**48.14%**	-0.349*	**-29.46%**	-0.237*	**-21.10%**
	(0.186)		(0.154)		(0.106)	
Medical School	0.556*	**74.37%**	-0.170	-15.63%	0.0831	8.67%
	(0.212)		(0.206)		(0.122)	
Law School	0.334+	**39.65%**	0.0868	9.07%	0.269*	**30.87%**
	(0.172)		(0.178)		(0.114)	
Licensing Staff/ M$ Research Funding	-12.24*	**-1.00%**	-6.574	-1.00%	-4.966+	**-0.99%**
	(5.300)		(4.873)		(2.605)	
Industry Research %	2.303*	**9.00%**	-0.110	-0.10%	1.463+	**3.32%**
	(0.924)		(0.884)		(0.874)	
TLO AGE	0.0307***	**3.12%**	0.0000600	0.01%	0.00729	0.73%
	(0.00684)		(0.00535)		(0.00447)	
Log Avg. Inv. Disc. T1			0.859***	**0.858%**	0.659***	**0.658%**
			(0.0938)		(0.126)	
Log Avg. Licenses T1					-0.235+	**-0.234%**
					(0.135)	
_cons	3.348***		-0.491		-0.751+	
	(0.585)		(0.571)		(0.421)	
N	76		75		75	
R^2	0.524		0.711		0.679	
adj. R^2	0.424		0.643		0.597	
F	10.38		27.80		10.12	

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.16 Regression Results, University Leadership Reporting & BS as Comparison

OLS (08-10)	(1) Invention Disclosures		(2) Licenses		(3) Startups	
Research Office	-0.171	-15.72%	-0.186	-16.97%	-0.310*	**-26.66%**
	(0.300)		(0.204)		(0.142)	
Economic/Bus. Dev.	-0.565	-43.16%	-0.215	-19.35%	-0.0526	-5.12%
	(0.414)		(0.243)		(0.159)	
Multiple Offices	0.0337	3.43%	0.478	61.28%	-0.374+	**-31.20%**
	(0.378)		(0.383)		(0.214)	
Director PhD	-0.0833	-7.99%	-0.359	-30.16%	-0.238	-21.18%
	(0.280)		(0.273)		(0.171)	
Director JD	-0.141	-13.15%	-0.814**	**-55.69%**	-0.122	-11.49%
	(0.335)		(0.259)		(0.220)	
Director MBA	0.367	44.34%	-0.321	-27.46%	0.0561	5.77%
	(0.294)		(0.274)		(0.191)	
Director tenure	-0.0237	-2.34%	-0.0103	-1.02%	-0.0115	-1.14%
	(0.0185)		(0.0147)		(0.0127)	
Private	0.393*	**48.14%**	-0.349*	**-29.46%**	-0.237*	**-21.10%**
	(0.186)		(0.154)		(0.106)	
Medical School	0.556*	**74.37%**	-0.170	-15.63%	0.0831	8.67%
	(0.212)		(0.206)		(0.122)	
Law School	0.334+	**39.65%**	0.0868	9.07%	0.269*	**30.87%**
	(0.172)		(0.178)		(0.114)	
Licensing Staff/ M$ Research Funding	-12.24*	**-1.00%**	-6.574	-1.00%	-4.966+	**-0.99%**
	(5.300)		(4.873)		(2.605)	
Industry Research %	2.303*	**9.00%**	-0.110	-0.10%	1.463+	**3.32%**
	(0.924)		(0.884)		(0.874)	
TLO AGE	0.0307***	**3.12%**	0.0000600	0.01%	0.00729	0.73%
	(0.00684)		(0.00535)		(0.00447)	
Log Avg. Inv. Disc. T1			0.859***	**0.858%**	0.659***	**0.658%**
			(0.0938)		(0.126)	
Log Avg. Licenses T1					-0.235+	**-0.234%**
					(0.135)	
_cons	3.546***		0.0446		-0.754*	
	(0.523)		(0.547)		(0.363)	
N	76		75		75	
R^2	0.524		0.711		0.679	
adj. R^2	0.424		0.643		0.597	
F	10.38		27.80		10.12	

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.17 Regression Results, Multiple Reporting & JD as Comparison

OLS (08-10)	(1) Invention Disclosures		(2) Licenses		(3) Startups	
Research Office	-0.205	-18.54%	-0.664+	**-48.52%**	0.0640	6.61%
	(0.305)		(0.354)		(0.211)	
Economic/Bus. Dev.	-0.599	-45.06%	-0.693+	**-49.99%**	0.321	37.85%
	(0.420)		(0.396)		(0.247)	
Institutional Leader	-0.0337	-3.31%	-0.478	-38.00%	0.374+	**45.35%**
	(0.378)		(0.383)		(0.214)	
Director PhD	0.0579	5.96%	0.455*	**57.62%**	-0.117	-11.04%
	(0.294)		(0.203)		(0.178)	
Director MBA	0.508	66.20%	0.493*	**63.72%**	0.178	19.48%
	(0.307)		(0.226)		(0.208)	
Director BS	0.141	15.14%	0.814**	**125.69%**	0.122	12.98%
	(0.335)		(0.259)		(0.220)	
Director tenure	-0.0237	-2.34%	-0.0103	-1.02%	-0.0115	-1.14%
	(0.0185)		(0.0147)		(0.0127)	
Private	0.393*	**48.14%**	-0.349*	**-29.46%**	-0.237*	**-21.10%**
	(0.186)		(0.154)		(0.106)	
Medical School	0.556*	**74.37%**	-0.170	-15.63%	0.0831	8.67%
	(0.212)		(0.206)		(0.122)	
Law School	0.334+	**39.65%**	0.0868	9.07%	0.269*	**30.87%**
	(0.172)		(0.178)		(0.114)	
Licensing Staff/ M$ Research Funding	-12.24*	**-1.00%**	-6.574	-1.00%	-4.966+	**-0.99%**
	(5.300)		(4.873)		(2.605)	
Industry Research %	2.303*	**9.00%**	-0.110	-0.10%	1.463+	**3.32%**
	(0.924)		(0.884)		(0.874)	
TLO AGE	0.0307***	**3.12%**	0.0000600	0.01%	0.00729	0.73%
	(0.00684)		(0.00535)		(0.00447)	
Log Avg. Inv. Disc. T1			0.859***	**0.858%**	0.659***	**0.658%**
			(0.0938)		(0.126)	
Log Avg. Licenses T1					-0.235+	**-0.234%**
					(0.135)	
_cons	3.438***		-0.292		-1.250**	
	(0.486)		(0.665)		(0.409)	
N	76		75		75	
R^2	0.524		0.711		0.679	
adj. R^2	0.424		0.643		0.597	
F	10.38		27.80		10.12	

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.18 Average Disclosures, Detailed Statistics

		AVGInvDisc		
	Percentiles	Smallest		
1%	6	6		
5%	12.66667	11.33333		
10%	20.33333	12.33333	Obs	76
25%	40.83333	12.66667	Sum of Wgt.	76
50%	84.5		Mean	121.4649
		Largest	Std. Dev.	111.0159
75%	162	359		
90%	310.6667	362	Variance	12324.53
95%	359	450.3333	Skewness	1.476691
99%	512.6667	512.6667	Kurtosis	4.770275

Figure 4.5 Average Invention Disclosures

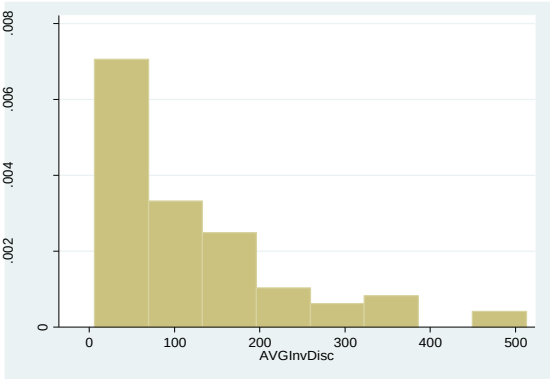


Table 4.19 Average Licenses, Detailed Statistics

		AVGLicenses		
	Percentiles	Smallest		
1%	0.6666667	0.6666667		
5%	2	1.666667		
10%	3	2	Obs	76
25%	7	2	Sum of Wgt.	76
50%	18.83333		Mean	24.98904
		Largest	Std. Dev.	22.91127
75%	41.33333	69.33333		
90%	57.33333	75.33333	Variance	524.9262
95%	69.33333	80.66667	Skewness	1.122249
99%	103.6667	103.6667	Kurtosis	3.772648

Figure 4.6 Average Licenses

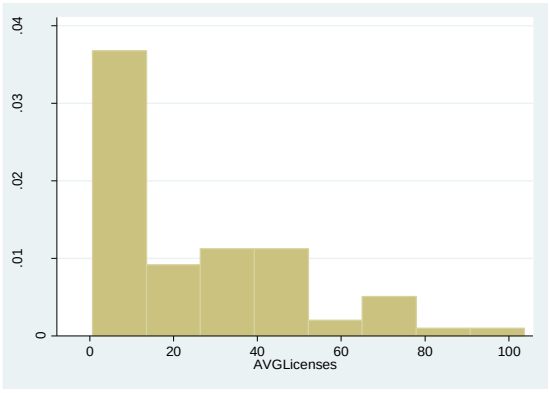


Table 4.20 Average Startups, Detailed Statistics

		AVGSTRTUP		
	Percentiles	Smallest		
1%	0	0		
5%	0	0		
10%	0.3333333	0	Obs	76
25%	1.333333	0	Sum of Wgt.	76
50%	2.666667		Mean	3.594298
		Largest	Std. Dev.	3.702385
75%	4.166667	11		
90%	9	11.66667	Variance	13.70766
95%	11	18.33333	Skewness	2.197896
99%	19	19	Kurtosis	8.61022

Figure 4.7 Average Startups

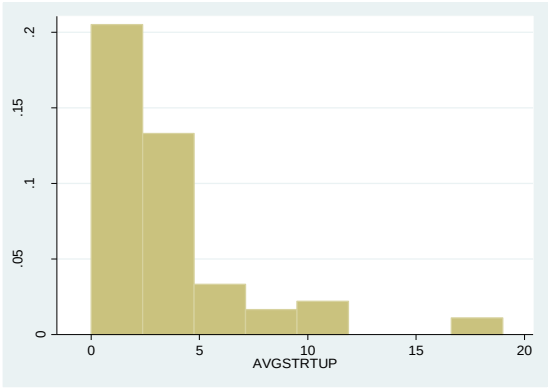


Table 4.21 Logged Average Invention Disclosures, Detailed Statistics

		LogAVGInvDisc		
	Percentiles	Smallest		
1%	1.94591	1.94591		
5%	2.61496	2.512306		
10%	3.060271	2.590267	Obs	76
25%	3.733495	2.61496	Sum of Wgt.	76
50%	4.448514		Mean	4.401166
		Largest	Std. Dev.	0.9566012
75%	5.093648	5.886104		
90%	5.741934	5.894403	Variance	0.9150859
95%	5.886104	6.112206	Skewness	-0.2184018
99%	6.241575	6.241575	Kurtosis	2.479071

Figure 4.8 Logged Average Invention Disclosures

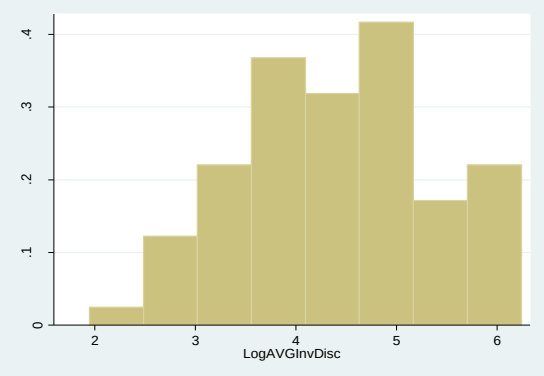


Table 4.22 Logged Average Licenses, Detailed Statistics

		LogAVGLicenses		
	Percentiles	Smallest		
1%	0.5108256	0.5108256		
5%	1.098612	0.9808292		
10%	1.386294	1.098612	Obs	76
25%	2.079442	1.098612	Sum of Wgt.	76
50%	2.98648		Mean	2.810995
		Largest	Std. Dev.	1.022706
75%	3.745296	4.253246		
90%	4.066174	4.33511	Variance	1.045928
95%	4.253246	4.402646	Skewness	-0.2129932
99%	4.650781	4.650781	Kurtosis	1.956492

Figure 4.9 Logged Average Licenses

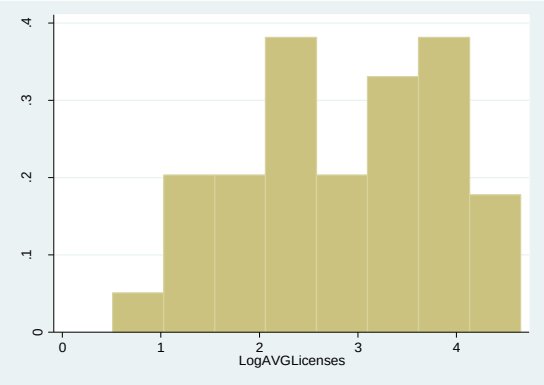


Table 4.23 Logged Average Startups, Detailed Statistics

		LogAVGSTRTUP		
	Percentiles	Smallest		
1%	0	0		
5%	0	0		
10%	0.2876821	0	Obs	76
25%	0.8472978	0	Sum of Wgt.	76
50%	1.299283		Mean	1.279339
		Largest	Std. Dev.	0.6927406
75%	1.641707	2.484907		
90%	2.302585	2.538974	Variance	0.4798896
95%	2.484907	2.961831	Skewness	0.1978639
99%	2.995732	2.995732	Kurtosis	2.842515

Figure 4.10 Logged Average Startups

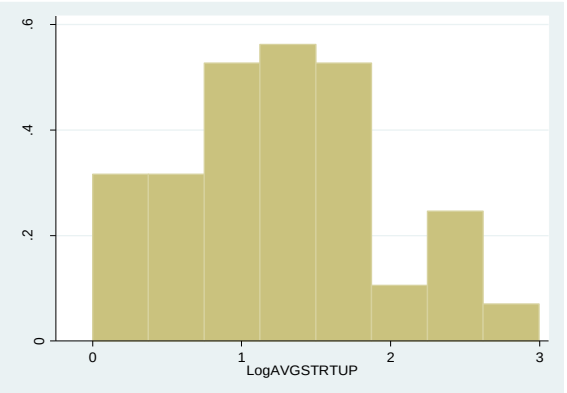


Table 4.24 Pearson Correlations, All Variables

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)	(s)	(t)	(u)
Log Avg. Inv. Disc. (a)	1																				
Log Avg. Licenses (b)	0.79	1																			
Log Avg. Startups (c)	0.74	0.52	1																		
Log Avg. Inv. Disc. T1 (d)	0.94	0.78	0.73	1																	
Log Avg. Licenses T1 (e)	0.84	0.90	0.55	0.87	1																
Log Avg. Startups T1 (f)	0.77	0.64	0.77	0.82	0.71	1															
Institutional Leader (g)	0.11	0.02	0.05	0.05	0.10	0.07	1														
Office of Research (h)	-0.08	-0.09	-0.13	-0.11	-0.13	-0.06	-0.55	1													
Economic/Bus. Dev. (i)	-0.08	-0.07	0.14	-0.03	-0.12	-0.08	-0.18	-0.52	1												
Multiple Offices (j)	0.11	0.24	-0.01	0.17	0.27	0.12	-0.13	-0.37	-0.12	1											
Director PhD(k)	-0.01	-0.03	-0.04	-0.06	-0.04	-0.08	0.31	-0.19	0.12	-0.24	1										
Director JD (l)	0.01	-0.10	0.07	0.06	-0.02	0.00	-0.02	-0.11	-0.10	0.36	-0.39	1									
Director MBA (m)	0.05	0.02	0.12	0.04	-0.02	0.12	-0.25	0.25	0.03	-0.17	-0.46	-0.27	1								
Director BS/BA (n)	-0.06	0.12	-0.15	-0.03	0.10	-0.03	-0.10	0.07	-0.09	0.12	-0.37	-0.22	-0.26	1							
Director Tenure (o)	-0.02	0.07	-0.12	0.05	0.16	0.12	-0.12	0.09	-0.13	0.18	-0.20	-0.20	0.17	0.26	1						
Private (p)	0.29	0.14	0.12	0.31	0.20	0.25	0.29	-0.24	-0.01	0.04	-0.02	-0.07	-0.07	0.19	0.14	1					
Medical school (q)	0.33	0.15	0.26	0.27	0.23	0.23	0.24	-0.29	0.14	0.01	0.25	-0.01	-0.25	-0.04	-0.05	0.20	1				
Law school (r)	0.37	0.27	0.39	0.34	0.29	0.33	0.05	0.04	-0.06	-0.06	0.15	-0.08	0.07	-0.19	-0.04	0.17	0.25	1			
TLO Age (s)	0.41	0.35	0.34	0.46	0.50	0.22	-0.10	-0.15	0.12	0.25	-0.14	0.19	0.03	-0.04	0.19	0.13	-0.10	0.04	1		
Industry Research % (t)	0.06	-0.03	0.18	0.04	-0.01	0.04	-0.14	0.14	0.00	-0.06	0.03	0.14	0.01	-0.19	-0.21	-0.19	-0.01	-0.07	-0.10	1	
LicStaff/M$Research (u)	-0.37	-0.40	-0.31	-0.35	-0.37	-0.32	-0.03	0.00	0.04	-0.01	-0.24	0.14	0.14	-0.01	-0.02	-0.05	-0.23	-0.21	-0.10	0.14	1

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