Knowledge Transfer to Industry at Selected R1 Research Universities in North Carolina

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Abstract: Public universities in the United States are divided into different levels of type by research agendas. Large public universities (typically known as **R1** research oriented universities) are directed to serve the public interest by developing transferrable knowledge (patents and intellectual property) that can leverage the public investment made in these large universities and their research agendas through state and federal funding by enhancing social and commercial goals of the funding entities. This paper is an *impact assessment of formal and informal industry collaboration and knowledge transfer activities study* and looked at technology transfer offices, secondary information and public reports such as patent filings to determine if the level of knowledge transfers was increasing or decreasing or staying the same at three large public universities in the USA (North Carolina, UNC Charlotte and North Carolina State) and two North Carolina R1 private schools (Duke University and North Carolina State University. My primary hypothesis for the research was that much of the research and knowledge at public universities was ***not*** finding its way to industry use either through licensing or other means and that various methods (i.e., research papers) of transferring this knowledge were ineffective in making this transfer. My research concluded that despite strong state and federal funding of this research as well as private grants researchers tended to concentrate on research that enhanced their academic publications' reputations which is resulting in fewer academic papers. The practical economic benefits of much of this research was doubtful since the correlation to outputs such as patents was not improving but plateauing over time in some cases.

Keywords: Knowledge transfer offices effectiveness; intellectual property; R1 universities

Paper Relevance: This research is important as R1 universities increasingly reward academics on grants, patents, revenue and papers produced for high impact journals as a way to gain promotion and status. This paper researches the various parameters to understand key technology transfer relationships to academic papers and patents produced.

1. Introduction

Dr. Vanover Bush is credited with being a major force behind creation of the strong government and defense partnerships that grew out of the *Office of Scientific Research and Development* (OSRD) created by US President Roosevelt in 1941. Bush (1945) laid out a vision for government-funded science and engineering that would unite academia, industry and (this being wartime) the armed forces. This it achieved by, in effect, keeping them apart. His plan was federal funding of academic research by the US government that was pure science followed by development in industry of both pure research and applied research. Gaining from both academic and business research would be the government which would source its projects to both. This plan ultimately led to the creation of the National Science Foundation (NSF) which in 2016 budgets over $7.724 Billion (National Science Foundation Budget Request 2016) to support science and engineering. In *Science, The Endless Frontier* (Bush 1945), a report to the president, Bush maintained that basic research was "the pacemaker of technological progress". New products and new processes do not appear full-grown," Bush wrote in the report. "They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science!" Science historian Daniel Kevles later wrote, Bush "insisted upon the principle of Federal patronage for the advancement of knowledge in the United States, a departure that came to govern Federal science policy after World War II".

As part of the Bush framework of uniting research partnerships, academic researchers have continued to work on both basic research and research funded by both the government and industry. The big corporations have outsourced the research portion of R&D and are now a shadow of their former research selves. Companies concentrate on incremental innovation of current products and their labs have slowed their winning of Nobel prizes in market ready semi-conductors, physics and chemistry (Nobel Prize 2016).

Companies are currently looking to obtain innovation form mergers and acquisitions of smaller research oriented companies rather than invest in their own facilities. Mergers and acquisitions is a strategy of firm growth that uses an acquisition through purchase of the stock or assets of a company to grow. Mergers

Reference this paper as: Harlow D, "Knowledge Transfer to Industry at Selected R1 Research Universities in North Carolina" *The Electronic Journal of Knowledge Management Volume 15 Issue 1 2017*, (pp3-16) available online at www.ejkm.com

frequently occur in order to grow the companies as a single related entity as well as develop economies of scale and scope. This should prompt more companies seeking innovation from university research but that is questionable and the results often meager. The traditional company separation of R&D suggested by Bush (1945) is giving way in industry to a strategic approach of Mergers &Acquisitions (M&A) coupled with limited purchases of innovation from university labs. M&A activities are those that involve either merging of two companies into one or an outright acquisition of a company by an acquirer. This strategy of letting other, often smaller, companies get technology to a market-ready level may signal the end of companies' research labs and of major industry breakthroughs in physics, chemistry and electronics.

Academics that are able to evaluate and read all the current research in any field are impossibly overloaded with the inconsequential as well as breakthrough research. This has prompted many academics to continue to publish narrow research in so-called top journals that is almost impossible to replicate while maintaining both their prestige and standing at R1 universities. The result of academic overload and narrow focus is research that has no effect on societal or state set goals and objectives of large state funded universities to 1) promote economic activity and 2) betterment of society. The end result: academic researchers writing to benefit careers and accumulate NSF funding rather than constituencies for public good.

University patent programs including technology transfer (TT) and patent licensing offices seem to be a very modest benefit to professors seeking to commercialize high-tech academic research. Research professors report that these TT programs hinder their ability to work as consultants with companies that show interest in their research, and fewer than half of university spin-off founders report that the ability to patent their research affirmatively helped their commercialization efforts (Love 2014). Rogers and Hoffman (2000) report that their effectiveness of technology transfer research shows the most correlation between the funding and the numbers of staff including faculty, support staff and graduate science and engineering graduate students.

This paper presents research of the monies spent and patent property transferred over the past 3-10 years at R1 universities in North Carolina and discussion of the Bush university-to-industry knowledge transfer model as well as the Bayh–Dole Act or Patent and Trademark Law Amendments Act (Pub. L. 96-517, December 12, 1980) Model. This paper concludes with a research comparison of the University of North Carolina's, University of North Carolina Charlotte, Duke and North Carolina State outcomes and research expenditures to give some quantitative numbers to check the validity or invalidity of the government stated strategy of positively effecting university research to industry transfer. Patents by each university are compared to basic research funding to test the hypotheses that R&D spending productivity as measured by patent transfer outcomes is valid. A comparison of 30 randomly selected universities from the 115 R1 universities is presented to add perspective and depth to this research.

Worldwide science and engineering(S&E) scholarly article output grew at an average annual rate of 2.5% between 1995 and 2007. The U.S. S&E growth rate was much lower, at 0.7%. The United States accounted for 28% of the world total S&E articles in 2007, down from 34% in 1995. The share of the European Union also declined, from 35% in 1995 to 32% in 2007. In Asia, average annual growth rates were high—for example, 17% in China and 14% in South Korea. As a result, in 2007 China moved past the United Kingdom, Germany, and Japan to rank as the world's 2nd-largest producer, up from 5th place in 2005 and 14th place in 1995.

The following Figure 1 summarizes the total papers being published by researchers at major research universities in the United States. From this chart it is clear that while expenditures have increased threefold-from $17B to over $50B-actual knowledge output as measured by publications has increased much less -from 140,000 per year to 220,000 per year; huge increases in funding at R1 universities has not resulted in more publishable results. From a baseline of $1.6 M paper published in 1994 that R&D funding per paper ratio has increased to $4.5 M R& D funding per paper published as of 2011-see Figure 1 below. This calls into question the system of grants and awards under the current system. However, this published paper result does track more closely the modest increase in numbers of researchers 150,589 in 1994 to 198,900 in 2011. Research is getting much more expensive at R1 universities without a corresponding increase in researchers and more researchers results in more papers.

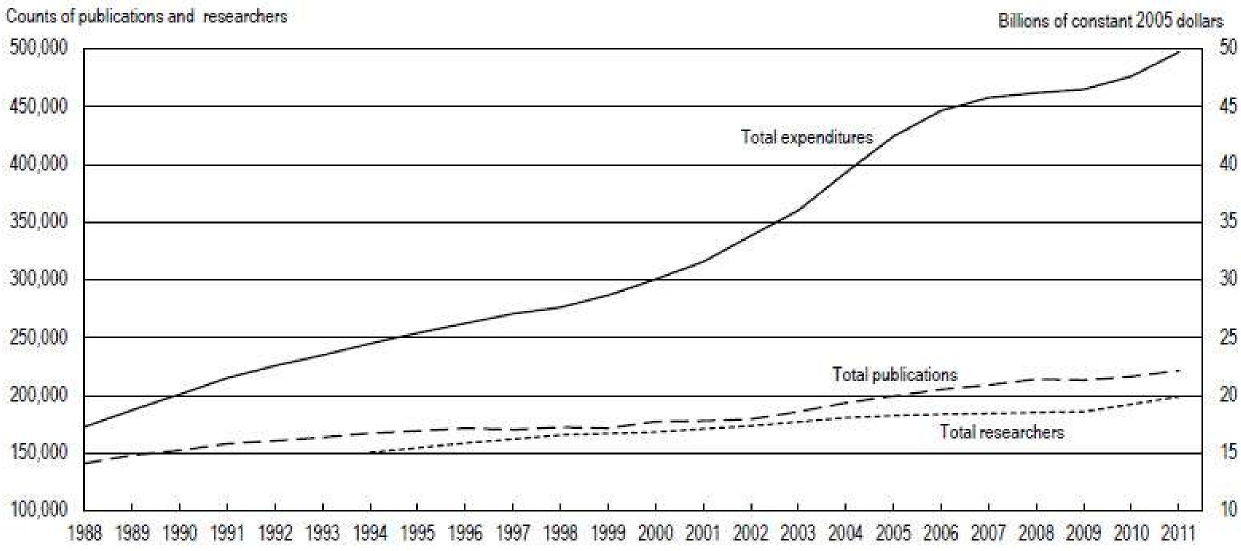

Figure 1: Academic R&D publications, researchers and expenditures (NSF 2016)

2. Literature Review

Indicators of academic patenting success are mixed. U.S. Patent and Trademark Office (USPTO 2015) data show that patents issued to U.S. universities declined to about 3,000 in 2008 from over 3700 in 1999. Other indicators relating to academic patenting suggest increasing activity from applications by major universities and university systems. A report from the AUTM (2014) indicates that 6,363 patents were issued to university research members in 2014. Their estimates of economic effect are over $28 billion in new product sales from 965 commercial products. In addition, they report over 914 start-ups from Technology Transfer Offices at research universities. Three technology areas have dominated these patent awards; chemistry, biotechnology, and pharmaceuticals accounting for 45% of the total patents awarded to U.S. universities in 2008 (AUTM 2014).

The Top 300 list of awarded patents to major United States research universities list includes the University of California (82nd on the list with 489 patents and up 7.9% for 2015), Massachusetts Institute of Technology (122nd on the list with 278 patents up 1.1 %), Stanford University (162nd on the list with 205 patents up 12.6%), California Institute of Technology (178th on the list with 183 patents awarded in 2015, up 6.4%), Columbia University (264th on the list with 119 patents, up 0.0%), University of Michigan (274th on the list with 117 patents , down 0.8%) (Intellectual Property Owners Association 2015). These major R1 universities all have budgets above one billion dollars per year with access to world class academics and facilities.

Data from another source (NSF 2014) show that invention disclosures filed with university technology management offices grew from 13,700 in 2003 to 17,700 in 2007 and that patent applications filed by reporting universities and colleges increased from 7,200 in 2003 to almost 11,000 in 2007.

The discussion of technology transfer rests on definitions of what is being transferred. Patents are part of the intellectual property mix for industry and academia and background in the literature addressing intellectual capital. The following sections of this paper addresses intellectual capital, innovation, patents and technology transfer to give the basis for the empirical research in this paper.

2.1 Intellectual Capital

Since this research is aimed at industry use from academic research. I have reviewed intellectual capital from that viewpoint. The *specific concept of intellectual capital* was introduced in the early 1990s which connected the idea of a firm's knowledge to the concept of firm intellectual capital to address valuation of intangibles and to further explain the idea of value creation and its relationship to firm performance (Edvinsson & Malone, 1997; Roos and Roos 1997; Stewart 1997; Sveiby 1997). According to a survey conducted by the International Center for Business Information, 97% of executives in eleven countries considered knowledge an essential part of value creation (Harlow 2014)**.** According to Von Krogh, Ichigo and Nonaka (2000), "the first responsibility of managers is to unleash the potential of an organization's knowledge into value creating activities".

A firm's knowledge and intellectual capital can be dynamically deployed and redeployed to form a basis for competitive advantage (Teece 2004). Strategic frameworks have been proposed to relate the role of knowledge to strategy (Von Krogh et al 2000) with astute management of the value in a firm's competence and knowledge base is a central issue in developing firm strategies (Nonaka & Teece 2001). Business has recognized that not all knowledge yields competitive advantage (Von Krogh et al., 2000). The Intellectual Capital Services (IC Index), originally developed in Scandinavia and Australia by Johan and Göran Roos et al (1998), identifies four categories of intellectual capital: relationship, human, infrastructure and innovation; it then looks at the relative importance of each, and also at the impact of changes in intellectual capital.

Stewart (1997) defines intellectual capital as the intellectual material-knowledge, information intellectual property, and experience that can be put to use to create wealth: it is formalized, captured, and leveraged to create wealth by producing a higher-valued asset. It is also the "sum total of everything everybody in the company knows that gives it a competitive edge (Stewart, 1998)". This it furthers the model of management directing the intellectual capital accumulation and use toward business outcomes.

"Much of the literature on intellectual capital stems from an accounting and financial perspective (Bontis, 2001d)". Many of these quantitative oriented researchers are interested in answering the following three questions:

1. What is causing firms such as IBM and Microsoft to be worth so much more than their book value?
2. What specifically is in this intangible asset?
3. What are the relationships between strategic intent, intellectual property, and firm performance and intangible asset book values?

The second question of 'what is this intangibles asset' leads to the definition and construct of intellectual capital from many researchers including Bontis (1999), O'Donnell (2004), Sallebrant et al. (2007), Curado and Bontis (2007) as:

1. Human capital
2. Structural capital
3. Relational capital

These *three constructs of intellectual capital* encompass the intelligence found in humans, organizational routines and both internal and external network relationships respectively. A potential confound in this construct is that the field of intellectual property typically looks at "organizational knowledge as a static asset in an organization (Bontis 2010)". This may have an actual impact as the knowledge of an organization and the capital is constantly changing. The behavior of knowledge-seeking individual and groups within the organization and the field of knowledge management relates at this point since it "focuses on the flow of information (Curado & Bontis 2007)". *Human capital* is further defined as the accumulated value of investments in the employee's training and competence (Edvinsson & Malone 1997). It also contains the competence, skills, and intellectual agility of the individual employees (Roos et al 1997). Zambon (2002) adds that human capital includes the collective knowledge, creativity and innovativeness of people within an organization. Systems, processes and intentional knowledge creation enable intellectual property generation. This is certainly true in an academic research setting.

A key to understanding *intellectual capital* resident in an organization is that those organization members must be able to recognize and express how that intellectual capital is expressed and how that core competence can be measured. A core competence is a necessary building block of world-class performance and ranking. The intellectual capital represents the sum total of all the unique and novel ideas that make the organization's capability and which taken as a whole determine the future of the organization. Accountants and financial analysts have avoided this area until recently because intellectual capital is an intangible that is only measured as the difference between book value and market cap. Even this indirect method is unsatisfactory since it is a static measure. "In the past, accountants have assumed a position which either ignores the problems or writes them off as impossible to solve. It is important to realize that intellectual capital is real and provides value (Andreou & Bontis 2007)." The rise of the Unicorns in Silicon Valley illustrates this problem since many companies are going public at a one billion dollar market cap while having almost no revenues or assets, other than intellectual property. This excess is thought to be the market valuation of the company's intellectual property. Licensing income of universities is another example of the value of intellectual property.

2.2 Innovation/ Invention

In this paper, I am discussing both invention (academic papers) and innovation processes (patents). Bright (1969) looks at innovation as a process served by discovery of a new scientific idea or concept that leads to a proposed theory or design concept synthesizing current knowledge and techniques to provide the theoretical basis for the technical concept. Trial and error is a common process employed. A verification stage of the theory or design concept ensues followed by a laboratory prototype or working model. At this point universities typically license further development and production of the product to an industrial enterprise through their patent and technology transfer offices. The commercial firm develops alternatives to the laboratory prototypes that lead to pilot production and full-scale commercial production and as the market gains acceptance to widespread adoption and competition as scale and customer usage spreads. Finally, proliferation occurs as products such as GPS become generic technology in capability and are applied to diverse and newly defined markets.

The use of patents in this above process allows the inventors to capture a significant amount of profit in early stage proliferation. Kuhn (1970) suggests two stages of scientific inquiry and maturation.
Universities are important contributors of innovation until the commercialization stage is reached since their focus is on the pre-commercialization stage of developing a pre-paradigm and eventually a paradigm of the new innovation idea.

Garud, Tuertscher & Van deVen (2013) have said that innovation is an outcome and that innovation pertains to the invention, development, and *implementation* of ideas. Innovation propagates across and within firms, multi-party networks, and within communities as well as through knowledge transfer through academic research and papers. Innovation may be hindered or helped by "four different kinds of complexities-evolutionary, relational, temporal, and cultural-complexities associated with innovation processes" (Bright 1969). Harnessing these complexities to manage or control such complexities may lead to sustaining innovation. This is where universities, with their differing criteria -such as numbers of journal articles published-of judging innovative ideas and research, get lost in the attempt to affect outcomes and transfer technology to commercial ventures through patent licensing and technology transfer offices.

2.3 Patents

Patenting high-tech inventions made on university campuses may not be a profitable undertaking, even at those universities best-positioned to profit from tech transfer (Agrawal 2001). Based on the patenting and licensing activities of survey respondents, Love (2014) estimated that university patent programs collectively earn a negative rate of return — an overall loss of more than three percent — on funds invested in high-tech patenting.

Patent rights and payments from those rights don't result in higher quality in high-tech fields or more or better research. "Eighty-five percent of professors report that patent rights are not among the top four factors motivating their research activities (Love 2014). Moreover, fifty-seven percent of professors report that they do not know how, or if at all, their university shares licensing revenue with inventors (Love 2014)".

Patents are part of the knowledge generating processes at firms. However, not all knowledge or patents have value nor can all knowledge be converted into value-creating activities. Since the 1990s, researchers in many areas, including that of strategic development of patented ideas, have attempted to understand how intellectual capital is generated at organizations and what effect this intellectual capital has on firm performance. Strategic frameworks have been proposed to relate the role of knowledge to strategy (Von Krogh et al 2000) with astute management of the value in a firm's competence/knowledge base as a central issue in developing firm strategies (Teece 1986). Teece (2004) further proposes that firms develop an intellectual property strategy that includes patents, trade secrets and copyrights to gain appropriability of patent and intellectual property use. These are important contributions but depend on valuable knowledge being created and disseminated by industry researchers and academics.

"Patents are protected by governments because they are held to promote innovation. There is significant evidence that they do not (Economist 2015)". Teece (2004) states that patents, in certain circumstances impede the flow of innovation by restricting the ideas that derives from the patent.

Another argument for patents is that they serve the public good. In return for registering and publishing your idea you get a temporary monopoly –usually 17-20 years-to use it. By giving the inventor a material gain through the exclusive right to use or license their innovation, the patent holder has an incentive to innovate for the social good or simply for monetary gain. Both outcomes yield income to the government.

Boldrin and Levine (2008) posit the argument that patents are neither good at giving a higher rate of innovation nor good at increasing the spread of innovation in the society. Their study compared other means of counting inventions and concluded that in the past countries that had strong patent systems were no less innovative than countries that had strong systems. Propagation of inventions was more related to the number of industry participants than the strength or existence of patents in industries from car-making to chemicals. Studies on wheat patents indicated that when patents on breeding of wheat crops was approved in 1970, subsequent improvement in yields were not shown nor was there an increase in spending on patents.

Patents are often an impediment to university research by 1) restricting access to patented research tools that are keys to the progress in one or more therapeutic areas and "rival-in-use- that will be used to develop a rival product in the marketplace. Another impediment 2) is the researcher use in clinical research of diagnostic tests involving patented technologies. Lastly, 3) major impediment to university research using patented ideas held by others is the often mistaken belief that research is shielded from the patent by the patent holders condoning of the research by non-enforcement (Merrill et al 2004).

According to data from the Intellectual Property Owners Association (2014) patents in the public company sector are down by a modest 0.8 percent in 2015. Of the top twenty companies issued patents, 11 of the 20 had a significant (over 8% decline in awarded patents). This may indicate a downward turn at major "older technology" companies whose labs have been replaced by mergers and acquisitions (Intellectual Property Owners Association 2015). Some technology firms continue to file patents at a rate that is increasing. For instance Qualcomm, an intellectual property (IP) business model firm that designs and licenses IP increased its filings by 18.6 per cent in 2015.

2.4 Technology Transfer

Technology is information put into productive use to accomplish some task. Technology transfer is the application of information into use (Rogers 1995). Technology Transfer Effectiveness (TTE) is the degree to which research-based information is moved successfully from one organization or individual to another. O'Keefe (1982) and Bozeman (1994) argued that "a lack of agreement on the conceptualization of Technology Transfer Effectiveness (TTE) is one obstacle to its study". No one measure of technology transfer effectiveness has been agreed.

A significant technology transfer USA government policy change since the Vanover Bush generated government policies of the early 1950's has resulted from the passage of the 1980 Bayh-Dole Act whereby almost all U.S. research universities (R1 and R2) have established an office of technology licensing intended to facilitate technology transfer to private companies. The Bayh-Dole Patent and Trademark Amendments Act of 1980, amended by Public Law 98-620 in 1984, facilitated patenting and licensing on a broad scale by research universities (Sandelin 1994). *This legislation shifted the responsibility for the transfer of technologies stemming from federally funded research, from the federal government to the research universities that conducted the research.*

The Bayh-Dole Act has been called "the 'Magna Carta' for university technology transfer" (Jamison 1999). According to Sandelin (1994), at least 60 percent of all invention disclosures at universities arise from federally funded research, and so university offices of technology transfer have defined their role on the basis of the Bayh-Dole Act. Sandelin (1994) concluded from his analysis: "By almost any measure, the passage of Public Law 96-517 [the Bayh-Dole Act] achieved the intended results: To encourage the disclosure and protection of innovation from publicly supported research; and to see the commercial development of products from such innovation for public benefit." The rise of biotechnology R&D and the life sciences in particular generated a huge increase in technology transfer offices and patents in the life sciences. The result is that 70% of patent licensing fees are generated from life science research with most of the remainder from physical sciences and engineering (AUTM 2014).

Other researchers have found that linear relationships between patents and academic research need more than a technology transfer office to succeed. Rogers& Hoffmann (2000) have reported that:

> *"Universities that are relatively more effective in technology transfer are characterized by (1) higher average faculty salaries, (2) a larger number of staff for technology licensing, (3) a higher value of private gifts, grants and contracts, and (4) more R&D funding from industry and federal sources".*

3. Research

Rogers & Hoffmann (2000) have proposed six measures of *technology transfer effectiveness*. This paper used this framework's (see list below) measures 1-4 and 6 in this study. I have added a measure of research effectiveness which is item 7, how does the total research expenditure at these universities relate to the number of patents both disclosed and revenues received. The following are the Rogers and Hoffmann (2000) measures proposed:

1. Invention disclosures received by a university per year;
2. U.S. patent applications filed;
3. Licenses/options executed;
4. Licenses/options yielding income;
5. Start-up companies formed;
6. Gross license income received by a university from its licensed technologies;
7. Gross monies spent on research at each university.

The publication of academic articles is one of several measures of academic research productivity, which includes, among other outputs, research & development (R&D) activities and funding patents and trademarks, copyrights, and licenses. The volume of peer reviewed S&E articles per 1,000 academic S&E doctorate holders is an approximate measure of their contribution to scientific knowledge (NSF 2016). North Carolina currently ranks tenth in the USA at 552 articles per 1000 S&E doctorate holders (North Carolina Innovation Report 2015). Over the past decade, the ratio of dollars spent at R1 universities to papers produced has increased from $250K to over $325K (Hale & Hamilton 2016). This leads to the question and my hypothesis of the relationship of peer reviewed papers to technology outputs such as patents and trademarks. Are patents licensed and papers produced both declining as R&D academic investment increases? What is the effect of Technology Transfer Offices at R1 North Carolina universities given estimated costs of $150k per full time equivalent (FTE) employee, $100k for other full time equivalent employees, and $30k per patent application? Legal fees and operational expenses of the Technology Transfer Offices are also a large expense.

3.1 Hypotheses and Research Questions

My paper has developed three hypotheses based on the above Burns-Hoffmann model/measures as follows:

> ***Hypothesis 1-*** *North Carolina R1 Universities (UNC, Duke, North Carolina State and UNCC) patents obtained is positively related to numbers of peer reviewed papers over the past five years.*
>
> > RQ1-What are the numbers of patents and papers produced per year at these R1 universities?
>
> ***Hypothesis 2-*** *R&D yearly monies spent at North Carolina R1 universities have a positive relationship to licensing and patent fees received at R1universities (UNC, NC State, Duke and UNCC) in North Carolina, USA.*

RQ1-What are the *yearly R&D and license fees* at these universities? What is the relationship of these two variables?

Hypothesis 3*-Technology Transfer offices budgets have a positive relationship to licensing fees and patents obtained at North Carolina R1universities.*

RQ1-What is correlation of the cost of the TT (technology transfer) office at these R1 universities to *patents*?

RQ2-What is the TT costs' correlation to *licensing fees*.

Variables

The variables used in this research were as follows:

- PAT=Patents/year
- R&D=R&D Expenditures per year
- LICF=Patent Licensing Fees
- SEP=Scientific and engineering papers/year
- TT=Legal and overhead Costs of Licensing Patents through the Technology Transfer Offices

3.2 Methods

My research used secondary data published by the National Science Foundation (NSF), Association of University Technology Managers (AUTM) and other available data to compare variables and answer the research questions using correlation of the five primary variables over a span of six years (n=6 for each variable).

3.3 Results (Table 1)

Hypothesis 1-This hypothesis SEP (papers relationship) is accepted for UNC Chapel Hill and for UNC Charlotte. The data shows positive correlation of SEP (papers) published to R&D expenditures for UNC Charlotte and a positive correlation for UNC Chapel Hill. While this does not reveal possible other positive effects of publication (i.e., citation power including numbers of cites) the actual numbers of peer reviewed science and engineering papers from UNC Chapel Hill and UNC to patents has a Pearson correlation of R=+0.54 (UNC Chapel Hill) and R=+0.17 at UNC Charlotte. This hypothesis is accepted for Duke and North Carolina State Universities which have an R=0.67 at Duke University and a more modest R=0.34 at NC State (see Table 1).

Hypothesis 2: This hypothesis (R&D to PAT) is accepted for UNC Charlotte. The Pearson R=0.98 presented in **Table 1** below LICF (License fees) is closely related to small relative number of patents.

At UNC Chapel Hill the Pearson R=0.75; this reflects that there is strong R&D to PAT correlation.

At Duke the Pearson R=0.67 indicates a strong correlation of R & D expenditures to PAT (patents).

At NC State the negative Pearson R=-.90 which is representative of the data showing that as R&D expenditures have increased issued patents have declined. For all of these results, the small sample size (n=7) of this correlation means that a there is a high volatility of results from year to year.

Hypothesis 3- The technology transfer office budget at North Carolina R1 Universities has a positive relationship to licensing fees and patents obtained?

The following are the two research questions for Hypothesis 3.

RQ1-What is correlation of the budget (cost) of the TT (technology transfer) at North Carolina R1 universities to patents?

RQ2- What is correlation of the budget (cost) of the TT (technology transfer) office at North Carolina R1 universities to licensing fees?

AT UNC Charlotte, the TT to PAT (patents) correlation is R=0.98 which indicates that as the budget increases the number of patent filings increase. The correlation of TT to LICF (licensing fees net) is R=0.99. This indicates strong positive correlation of TT to LICF (licensing fees). As TT increases the number of patents increases on an approximate 1:1 basis.

At UNC Chapel Hill, the TT to PAT correlation is R=0.76. As budget for the TT office increases there is a positive effect on the numbers of patents filed. The TT to LICF correlation is R=-0.74. This TT to LICF correlation is the result of significant negative net licensing income (expenses exceed revenues) for one year of data.

At North Carolina State the correlation TT to PAT is R=-0.19 which shows a modest negative correlation of technology transfer office costs relative to the output number of patents (PAT). As each patent is developed by the TT office the costs per patent are slowly being reduced but within a small range over each year. The Pearson Correlation is R=0.05 for TT relationship to LICF (licensing fees). This indicates that very little of the budget of the TT office may be producing licensing fees. The TT office has little relationship to the licensing *or* the patents produced. Both correlations are very small to insignificant.

At Duke, TT to patents correlation is R=+0.96 which indicates a positive correlation of TT to PAT (patents). From the data, what is discerned is that as TT office costs fees increase over time the patents produced increase. On a close to 1:1 basis, the direction of TT office expenses is negatively related to licensing income with an R=-.85. This indicates that licensing fees may be cumulative and increase at large rates of increase without more budgets funding for the TT office. The raw numbers support this conclusion with a sudden jump in licensing fees occurring at intermittent intervals.

At Duke, as TT office budgets increase there is a negative correlation effect on patents produced and more budget for the TT office does not positively affect licensing fees.

Table 1: Pearson R Correlations of Variables at UNCC, UNC Chapel Hill, Duke, North Carolina State and 30 Comparable R1 Universities

University	PAT to SEP	R&D to LICF	R&D to PAT	TT to PAT	TT to LICF
UNC Charlotte	R=0.17	R=-0.97	R=0.98	R=0.98	R=0.99
UNC Chapel Hill	R=0.54	R=0.75	R=0.75	R=0.74	R=0.75
NC State	R=0.34	R=0.98	R=0.09	R=0.19	R=0.05
Duke	R=0.67	R=0.56	R=0.67	R=0.85.	R=0.86
30 Comparable Selected R 1 Universities	R=0.51	R=0.63	R=0.71	R=0.52	R=0.77

The above Table 1 also compares the results of this four North Carolina R1 university sample research with 30 comparable (out of the list of 115) R1 universities. PAT to SEP correlation is R=0.51 which is moderately correlated. R&D to LICF has a higher correlation which is R=0.63. R&D to PAT is R=0.71 which is comparable to our primary sample and a strong correlation. TT to PAT has a lessor value of R= 0.52 but still moderately related. TT to LICF is a strong relationship of R=0.77 which is comparable to 3 of 4 universities-UNC Charlotte, UNC Chapel Hill and Duke-in our sample. Based on this comparison, it appears that the correlations obtained in this study were close to a broader sample of R1 universities.

Tables 2 & 3 below summarize the source data.

Table 2: UNC Charlotte and UNC Chapel Hill Patents Generated per R&D ($M) & Per Patent $ Legal.

Year	2009	2010	2011	2012	2013	2014
UNC Charlotte- Patents Issued	12	7	9	5	6	11
UNC Charlotte R&D $M/Patent	2.43	4.54	3.05	5.02	4.11	2.11
UNC Charlotte Legal K$ Fees Per patent	30.0	30.0	30.0	46.2	39.2	32.0
UNC Charlotte Total TT Costs K$	360	360	360	234	234	352
UNC Chapel Hill- Patents Issued	55	39	26	39	38	36
UNC Chapel Hill R&D $M/Patent	13.04	20.59	30.31	19.67	20.47	22.00
UNC Chapel Hill k$ Legal Per Patent	92.3	92.1	92.1	97.4	87.2	92.1
UNC Chapel Hill Total TT Costs M$	3.43	3.24	3.54	3.79	3.53	3.59

Table 3: NC State and Duke Patents Generated per R&D ($M) & Per Patent $ Legal.

Year	2011	2012	2013	2014
NC State Patents Per year Issued	51	45	40	40
NC State R&D $M/Patent	7.4	8.4	10.4	11.2
NC State Legal K$ Fees Per patent *	92	92	92	92
NC State All TT Costs M$*	8.70	9.27	9.15	88.64
Duke Patents /Year Issued	52	50	41	49
Duke R&D $M/Patent	16.4	16.8	19.6	18.3
Duke k$ Legal Per Patent*	152	161	144	80
Duke All TT Costs M$	15.8	16.40	15.19	11.56

*Estimated. (Trune & Goslin 1998). All other amounts listed are actual.

4. Research Limitations and Conclusions

A limitation of my research is that the comparison may be difficult since the scale of the differences between UNC Charlotte and the other three universities is so great. In addition, Duke is considered to be a top (i.e., Stanford, Harvard, Yale, Cornell, Princeton) R1 *private* school which has resources and endowments ($7.37 B) (Duke Endowment 2016) that give them an advantage in directing money toward research. Considering the respective R&D budgets of $26.7M average per year over the past 6 years (UNC Charlotte), over $719M average per year at UNC Chapel Hill, $400M at NC State and over $1,000M at Duke patent fees are very modest at the major universities compared to the performance of the least funded university. Duke at # 7, North Carolina at # 8 and North Carolina State AT #51 in R&D budgets, as of end of 2014, are all major research- oriented R1 schools (NSF 2016).

The number of patents obtained each year at UNC Charlotte, UNC Chapel Hill, North Carolina State and Duke averages 8, 35, 44 and 48 patents per year, respectively. With only 3.5% of the funding of UNC Chapel Hill, UNC Charlotte is patenting at over 20% of the rate of other RI North Carolina universities. This result strongly implies a more focused and effective TT office. License fees at UNC Chapel Hill, NC State and Duke are very different and over 40 times the license fees at UNC Charlotte and this indicates higher valued patents and the very much smaller budgets at UNC Charlotte. This may be related to the science and medical focus of both patents and research at UNC Chapel Hill. The following is a brief of comparable (R&D budget) universities for the past four years of patent awards.

Table 4: Number of Awarded Patents by Leading R1 Universities (2012-2015) (IPO 2016)

University Name	Budgeted 2015 B$	2012	2013	2014	2015
Cal Tech	.37	111	147	172	189
University of Texas	.62	145	169	174	191
Wisconsin	1.2	144	160	153	161
John Hopkins	2.1	120	132	140	143

The above table shows the patent lag that Duke, UNC Chapel Hill and NC State have with regard to other comparable institutions. With budgets for the three North Carolina universities totaling almost $2.1 B per year in 2015, it is apparent that North Carolina R1 Universities are not as focused on patents as other major R1 universities. Patents at leading R1 universities result from lessor R&D expenditures.

Academic Science and Engineering papers published at each university have a positive relationship at UNC Chapel Hill and a negative relationship at UNC Charlotte to patents issued. Again this relationship indicates that the type of patents and the market value of ideas as well as much greater access to TT staff are providing a conduit for research. Fewer S&E papers are being written at Charlotte with patents staying relatively the same year to year. However, licensing income is increasing at Charlotte at an increasing rate and costs of the TT office are roughly equal to that percentage increase in income (See Figure 1). Licensing income at UNC Chapel Hill is increasing year-to-year between 2013 and 2014 as well over the past 3 years at a rate higher than expected given the decrease in numbers of patents (from 38 in 2013 to 36 in 2014). Science and engineering academic publishing at Duke and North Carolina State have a positive relationship to R&D at those universities.

For the latest year, the North Carolina universities do better when compared in journal impact rankings (papers) than in patent performance according to the Leiden CWTS rankings (Leiden 2016). For 2016, Duke ranks 14th, North Carolina Chapel Hill 24th, NC State 113th and UNC Charlotte 162nd. This ranking is based on the impact factor "p" of the papers and compares universities globally and in regions. These rankings roughly correspond to their R&D expenditures ranking in the USA.

The relationships of technology transfer offices, patents filed and overall regional and state of North Carolina GDP growth as well as new ventures is *not clear-cut*. The cost of these offices is poorly correlated to the knowledge advancement through journals and royalties earned from patents and licensing (See Figure 1 above). Charlotte's growth in income ranking of US cities places it second over the past two years with much lower R&D spent per capita than the Research Triangle. Money spent per capita per region does not appear to be a key driver in technology generation and transfer (AUTM 2015). The UNC Chapel Hill area is rated lower in growth so a simple answer is not forthcoming to the value of R&D at state universities and their TT offices effect on the local and regional economy.

Science and Engineering academic papers published at UNC Charlotte and UNC Chapel Hill diverge in their relationship to patents with a strong relationship at UNC Chapel Hill and a negative relationship at UNC Charlotte. The findings are indicative of the need for a higher emphasis on academic papers at UNC Charlotte or the lack of a medical school at UNC Charlotte that drives new patentable technology in biomedicine and medical related fields. NC State also has a lower correlation of academic papers published to patents produced. The Duke numbers are impressive and related strongly to the numbers of papers that are medical and related to their teaching hospital and medical research centers. My research shows that Duke is first in publishing of academic papers in the science and engineering area in North Carolina. While overall budgets at both Duke and North Carolina Chapel Hill are similar, Duke's costs of technology transfer greatly exceed the costs at other schools and on a simple measure of R&D cost per paper published.

This research is important as public policy is developed to track the relative slowing of academic publishing over the past 10 years at all of these universities and US universities (more R& D spent per paper produced) and the increased funding at UNC Chapel Hill, Duke, North Carolina State and decreased government R&D funding at UNC Charlotte. Public policy may be slanted toward funding the "name" R& D North Carolina schools over the less well known but important UNC Charlotte located in the largest city and fastest regional growth area of North Carolina. A public policy that included a medical school for UNC Charlotte would even out the patent and paper outputs more over time.

The major patent and paper outcome differences between these universities may be related to the higher salaries for R&D academics at UNC Chapel Hill, Duke and North Carolina State relative to Charlotte (over 20% more $/year on average). The much greater numbers of staff for technology licensing-4 at Charlotte vs. 25 at UNC Chapel Hill, 26 at Duke and 19 at North Carolina State-and much higher funding from both private sources and industry and federal contracts has a significant impact on outcomes. This research gives strong indicators that major change is needed in the Vanover Bush model yield both more basic and market-ready research.

My conclusion is that output(legal, licensing, managing) of Technology Transfer Offices at major R1 universities adds significant costs to the R&D licensing effort without rewarding researchers($.1.2 Net Income for researchers at UNC Chapel Hill) or universities with more licensing fees or universities with more patents per research dollar spent. A new approach to R1 research based on a different model than the Bayn -Dole Act is strongly recommended from the data in this paper based on the limited outcomes under that Bayn Dole model and the huge costs incurred without requisite income to researchers or to society.

Further, the model of transferring R&D funds to universities and getting societal benefits in the form of increased knowledge is fraying badly around the edges. I recommend a new model of research that needs to separate the technology development from basic research and fund universities to do both practical research and basic research with different requirements for authoring of that knowledge to advance academic careers. Basic research should be freely shared with the public and other institutions and technology development should be focused on technology transfer to yield more than royalties, instead the development of more incubation businesses would be the defining criteria.

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