A Preliminary Study of the Impact of Resource Allocation on Licensing Outcomes of Academic Institutions in the United States

Arundeep S. Pradhan[1*], Raymond A. Wheatley[1], Michael A. Batalia[1] Joseph Janda[2], Ge Zhao[3]

[1]Apio Innovation Transfer, Portland Oregon; [2]Office of the Vice President of Research, Research and Graduate Studies, Portland State University, Portland, Oregon; [3]Fariborz Maseeh Mathematics and Statistics, Portland State University, Portland, Oregon

*Corresponding Author
Email: arundeep@apioix.com

Abstract

Academic technology transfer is an increasingly visible function that has gained importance due to its proven, positive impact on the economies of cities, states, and nations. While there has been robust study of overall economic impact, there is a dearth of research on the impact of institutional resource allocation – the distribution of resources within technology transfer offices – on technology transfer outcomes, and in particular, licensing outcomes. Preliminary research was conducted using data from the 2012-2018 AUTM Licensing Activities Survey. The analysis focused on workload and the impact of staff and legal expenses on the numbers of licenses executed. Statistical analysis shows the size of the research enterprise, total staff, licensing staff, and non-licensing staff all had a positive association with the numbers of licenses executed. On the other hand, legal fees associated with intellectual property protection had a negative association with the number of licenses executed.

Introduction

The Bayh-Dole Act, which was passed on December 12, 1980, gave rise to the profession of academic technology transfer (TT). Bayh-Dole is referred to as "Innovation's Golden Goose" and "perhaps the most inspired piece of legislation to be enacted in America…[which] unlocked all the inventions and discoveries that had been made in laboratories throughout the United States with the help of taxpayers' money. More than anything, this single policy measure helped to reverse America's precipitous slide into industrial irrelevance[1]." Forty years later, TT has grown to become an important, driving force in the United States, adding $1.7 trillion to the economy and up to 5.9 million jobs since 1996[2]. In the four decades since the inception of TT, the role and scope of TT offices (TTO) has changed to include a number of activities (Figure 1). However, licensing academic innovations remains the core activity for a TTO[3,4].

Studies have shown most institutions do not generate enough income from their TT efforts to recoup the expenses of maintaining a TTO[5]. There is evidence of significant variability in the performance of individual institutions in translating technology opportunities into products[6]. Also, there is evidence the innovation ecosystem is slowing in the United States[7]. These factors, when coupled with the reality of limited resources dedicated to TT at most institutions, beg the examination of TTO resource allocation and its potential impact on licensing outcomes.

There have been prior assessments from a number of different perspectives, Previous studies have been directed to measurement of TTO performance, their efficiencies of converting research to patents and licenses[8, 9], as well as examinations of metrics established to measure performance[10, 11, 12], including metrics developed for other non-commercial entities engaged in TT, such as U.S. government agencies[13]. Considering the limited financial resources available to most TTOs, there have been some studies focused on strategies to reduce patent expenditures[14, 15]. While those studies are meaningful, they do not tell the entire story. For example, there is no understanding of the impact of patent expenses versus more resources for staff, marketing, or professional development on the success of a TTO.

This is important because the two primary budget categories for TTOs are operations and legal. The operations budget includes licensing and non-licensing staff and other categories, whereas the legal budget is dedicated to intellectual property protection; the bulk of which is patent expenses. In one study, patent expenses constituted over 44% of a TTO's total budget[16]. That said, staff and legal expenses are generally the largest areas of allocation. Other budget categories include supplies, travel, professional development, and in some cases technology development funds (also referred to as "gap funds").

Finally, with regard to prior research on resource allocation, copious studies exist in the for-profit sector but very little in the non-profit sector, and none directed specifically to academic TTOs. The limited research available for academic institutions has focused on the effect of resource allocation on student outcomes and teaching, which are important aspects of institutions.

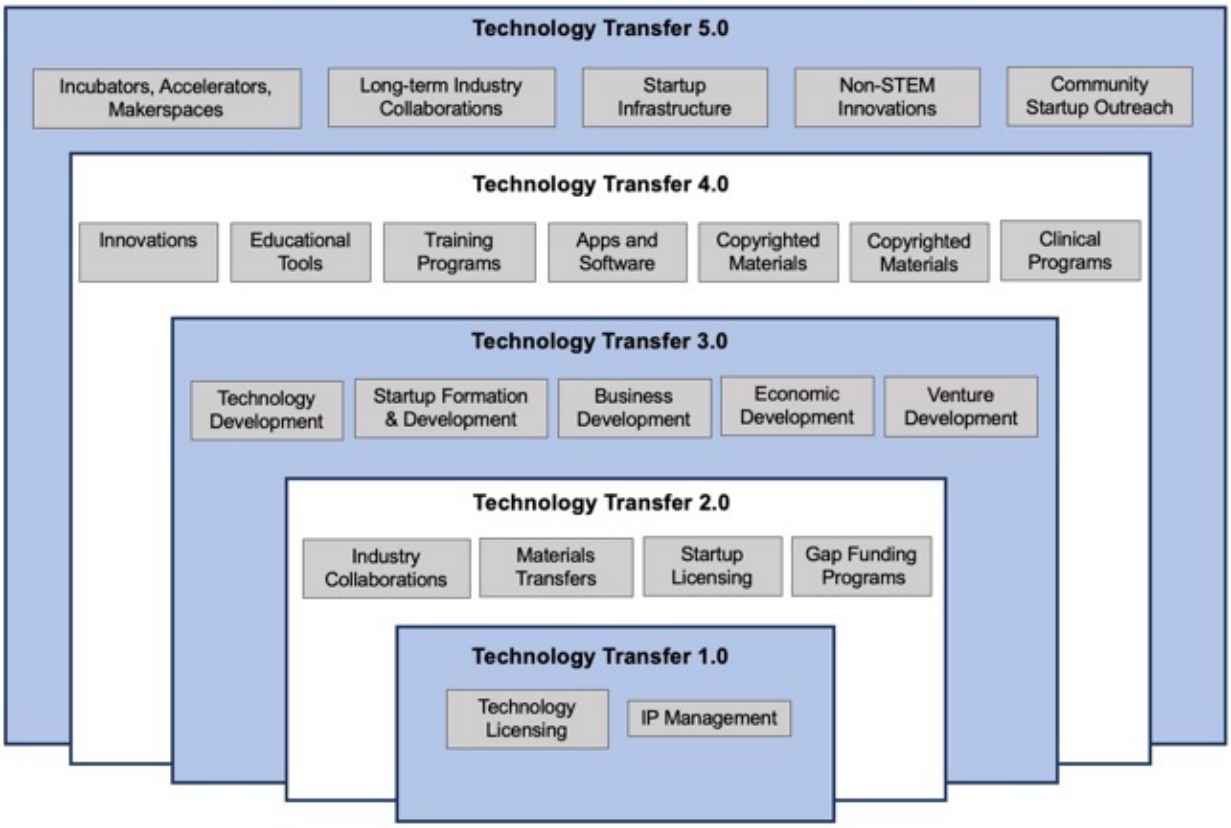

Figure 1: *Evolution of Technology Transfer*

Research as conducted using data from the AUTM Licensing Activities Survey (LAS). The data collected by the LAS includes the numbers of licensing and non-licensing personnel, the amount spent on legal fees and total unreimbursed legal fees, the number of licenses executed, and the total number of innovations and patents licensed. This data provides resources to help understand the complex issues of academic technology transfer, however, it limits insights into the operations of a TTO. LAS data does not reflect the longitudinal aspect of the TT process. For example, it might take over a year from the date an invention disclosure is received to file a patent application, and several years before a patent is issued, a license is executed, and licensing revenue is realized. Therefore, the data at best represents trends in the profession.

Using data collected by LAS from 2012-2018, an analysis was done to assess the impact of resource allocation on licensing outcomes within a TTO, focusing on 1) workload, specifically invention disclosures per licensing staff and total staff, and 2) the impact of total staff, licensing staff, non-licensing staff, and legal expenses on the numbers of licenses executed. The LAS provides data on the numbers of licensing and non-licensing staff (but not the budget for staff), legal expenses incurred, and legal

expenses reimbursed (by licensees). The LAS does not provide any information on the specific responsibilities of non-licensing staff or other internal TTO budget allocation.

Results

The size of the research enterprise of US institutions varies greatly, making it difficult to compare an institution with research expenditures of $10MM to one with research expenditures of $1.0BB. Therefore, institutions were divided into four quartiles based on the research expenditures reported in the LAS. Institutions in quartile 4 had the largest research expenditures, stepping down to the smallest in quartile 1. LAS data was compiled and examined to assess the influence of different elements on the number of licenses executed within the quartiles and for all institutions and a statistical analysis performed. (See *Methods and Materials* for specific details.) The overall trends for TT indicate increases in absolute numbers for all significant metrics – research expenditures, TTO staffing levels, numbers of patent applications filed, patents issued, number of invention disclosures licensed, and numbers of licenses executed and a disproportionate increase in legal fees.

Prior to quantitative analysis of the data, a survey was conducted of TTO directors to determine perceived definitions of success and resources deemed critical to success. The majority of TTO directors surveyed (n=48) defined success by number of licenses executed, and the resources identified as being critical to TTO success were licensing staff, legal fees, and startup support.

Key Findings

Statistical analysis showed that the size of the research enterprise, total TTO staff, licensing staff, and non-licensing staff all had a positive association with the numbers of licenses executed. Legal fees on the other hand had a negative association with the number of licenses executed. This is of particular interest considering that one of the biggest expenditures a TTO incurs is legal fees. Additionally, legal fees are increasing at a higher rate than invention disclosures and other key TT metrics. Other key findings include:

- There is a significant variation in the size of research enterprises. This is due, in great part, to consolidated reporting by large state university systems (e.g. the University of California System) that aggregate data from all institutions in the system.
  - The size of the research enterprise for Institutions in quartile 4 averaged $4.53BB vs $77MM for institutions in quartile 1.
  - Research expenditures per invention disclosure varied from an average of $2.92MM per invention disclosure for quartile 4 institutions to $1.64MM for quartile 1 institutions.
- Institutions in all quartiles showed growth in TTO staffing levels albeit at different rates.
  - Quartile 1 institutions showed the lowest level of growth at 3.8%.
  - Total TTO staff grew by 40% for quartile 2 institutions – the highest among the four quartiles.
  - The ratio of licensing staff to non-licensing staff was relatively stable for quartiles 1, 3, and 4.
  - The percentage of licensing staff to non-licensing staff for quartile 2 institutions dropped from 51.7% to 43.9%.
- Workload and work output varied greatly from quartile to quartile.
  - The average invention disclosures per licensing full-time equivalency (FTE) and total FTE for quartile 4 institutions was 24.0 and 10.26 respectively versus 16.61 and 8.92 for quartile 1 institutions.
  - Quartile 2 institutions showed a significant decrease in invention disclosures per total FTE dropping from 9.86 to 8.32, while remaining relatively steady at an average of 18.27 invention disclosures per licensing FTE.
  - Licenses per licensing FTE increased for institutions in all quartiles except for institutions in quartile 1.
  - Quartile 2 institutions had the largest increase in the proportion of non-licensing staff.
  - The largest increase in licenses per licensing FTE was seen in quartile 2 institutions, from about 3.75 to 5, and seems commensurate with the increase in non-licensing staff.
- Legal fees incurred increased for institutions in all quartiles except for quartile 1.
  - Quartiles 3 and 4 showed the greatest increases at 37.5% (from $194.9MM to $266.6MM) and 36.8% (from $69.3MM to $89.7MM) respectively.
  - Quartile 1 had the greatest percentage of unreimbursed legal fees (approximately 68%).

- Quartile 4 had the lowest percentage of unreimbursed legal fees (approximately 52%).

The 2012-2018 LAS data reveals growth in all areas except licensing income. The research enterprise has grown by 16%, total invention disclosures received by 11%, and total licenses executed by 22.9%. There has also been growth in staffing levels by 18.4%. However, total legal fees and unreimbursed legal fees seem to have increased disproportionately by 30.5% and 30.0% respectively, whereas patent applications filed grew by 21.8% (Table 1).

TABLE 1: Percent increase/decrease in key performance indicators of technology transfer

Category	2012	2018	% Change
Total Research Expenditures	$58,209,884,118	$67,497,222,790	+16.0%
New Disclosures	21,545	23,915	+11.0%
Invention Disclosures Licensed	7,512	10,608	+41.2%
Percentage of Disclosures Licensed	34.87%	44.36%	+27.22%
Total Patent Applications Filed	19,855	24,192	+21.8%
Total Legal Fees Incurred	$314,349,479	$410,324,881	+30.5%
Total Legal Fees as a Percent of Total Research Expenditures	0.54%	0.61%	+12.96%
Total Legal Fees Reimbursed	$145,231,402	$190,440,172	+31.1%
Total Legal Fees Unreimbursed	$169,118,077	$219,884,709	+30.0%
Total Licenses Executed	4,854	5,964	+22.9%
Total Licensing FTEs	979	1090.8	+11.4%
Total All FTEs	2087	2470	+18.4%
Gross Licensing Revenue	$2,353,231,081	$2,292,475,774	-2.6%

Resource Allocation, Defining Success, and Contributors to Success

As previously noted, the majority of the funds within a TTO's budget are directed to legal (for intellectual property protection) and staff (licensing and non-licensing) with relatively small allocations to areas such as marketing and professional development. Like any organization, a TTO's success depends on the total resources allocated (dollars, staff, and support), as well as the manner in which they are allocated within the TTO. It is important to note that there is a great deal of variation on TTO structures based on the size of the research enterprise and the TT goals of the institution.

The general sentiment in the profession is that ultimate TTO success is the number of products that are brought to market. However, it is not the direct responsibility of TTOs to bring products to market. As such, licenses executed seem a more appropriate metric of success. To confirm this, a survey was conducted to learn how TTO directors define success. The respondents were asked to choose their top three measures of success (limited to what is controllable by a TTO), as well as their perception of the top three measures of success used by their institution's administration (Figure 2).

TTO director success metrics varied when compared to their perception of their administration's definition of success. The top three measures of success for TTO directors were licenses executed, faculty satisfaction, and invention disclosures received. In contrast, the top three measures of success for an institution's administration were licensing revenue, faculty satisfaction, and startups created.

Faculty satisfaction is common to both and has been linked, anecdotally, to actions such as prompt acknowledgement of receipt of the invention disclosure, timely assessment of the intellectual property and commercialization potentials, marketing efforts, intellectual property protection (if warranted), and licensing. Faculty satisfaction is a subjective measure which is viewed by TT leadership as an indicator of the confidence that faculty has in the TTO.

Respondents were asked which three budget line items of a TTO budget they felt contributed most to the office's success (Figure 3). TTO directors responding to the survey indicated the top three TTO budget line items most crucial to the success of the TTO are licensing FTE, funds for obtaining intellectual property protection (the same as total legal fees incurred in the LAS data), and startup support programs.

This is consistent with the general sentiment that licensing FTE and intellectual property protection are viewed as critical elements of the ability to of TTOs to transfer innovations to industry.

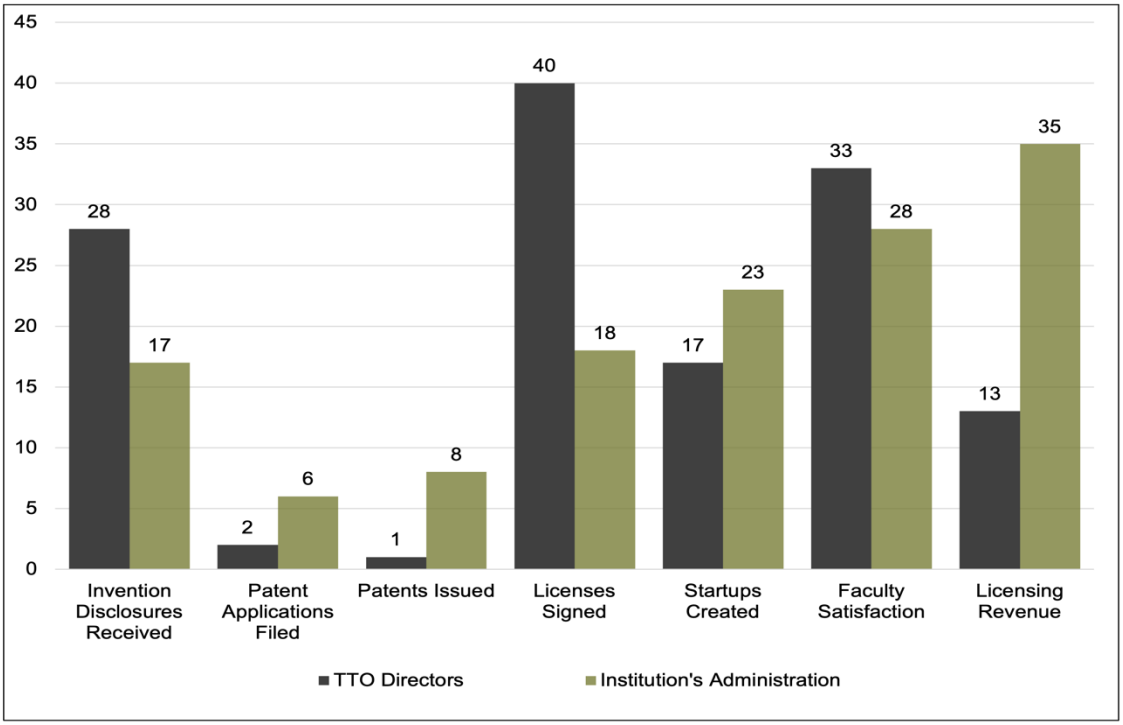

Figure 2: *Top three areas of resource allocation within a TTO Measures of success as defined by TTO directors versus institutional administration*

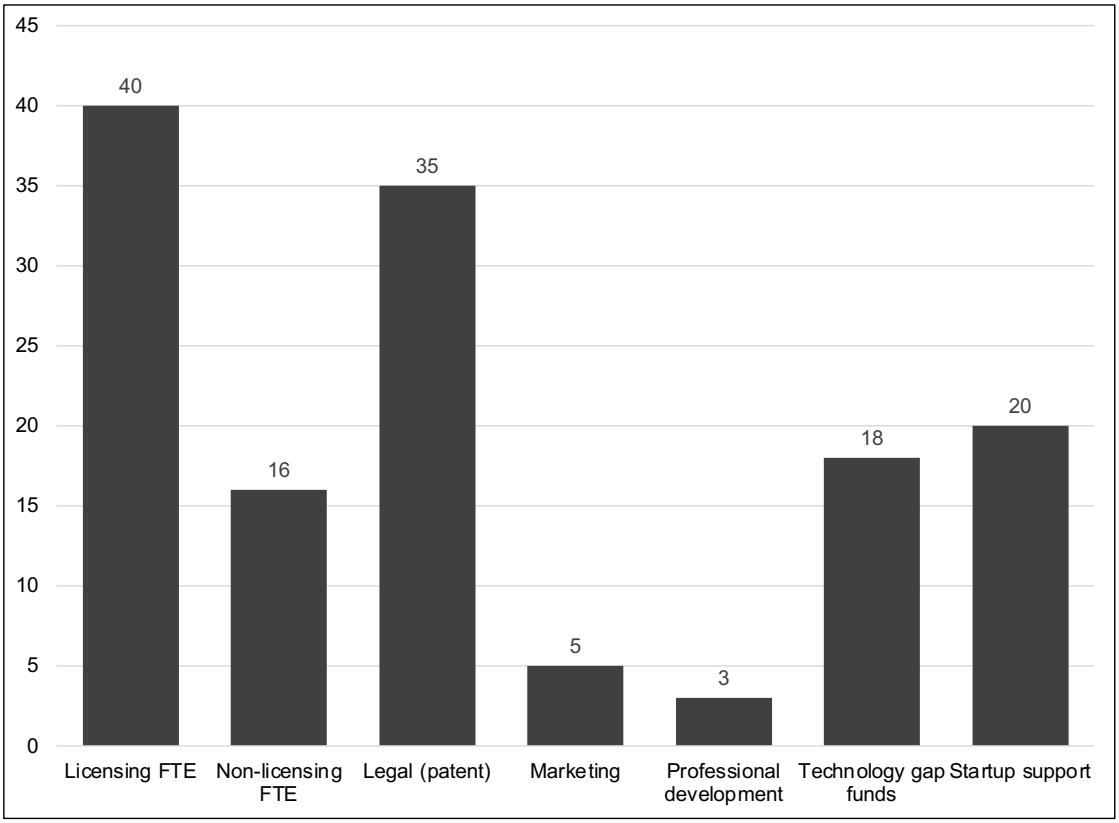

Figure 3: *Top three areas of resource allocation within a TTO*

Factors that Influence the Success of TTOs

The LAS is currently the best available source of information on TT licensing and intellectual property protection activities. Understanding how limited resources are employed within a TTO to promote success is important to determine the relative impact of different functions within the TTO but much of that data is not collected by the LAS. As such, the factors analyzed were 1) the size of the research enterprise, also known as research expenditures; 2) office staffing, broken down by total staff, licensing staff, non-licensing staff; and 3) legal fees expended.

1. Research Expenditures

The research enterprise drives the operations of a TTO by giving rise to innovations with potential commercial applications. Research expenditures reported in the LAS are shown by quartile (Figure 4).

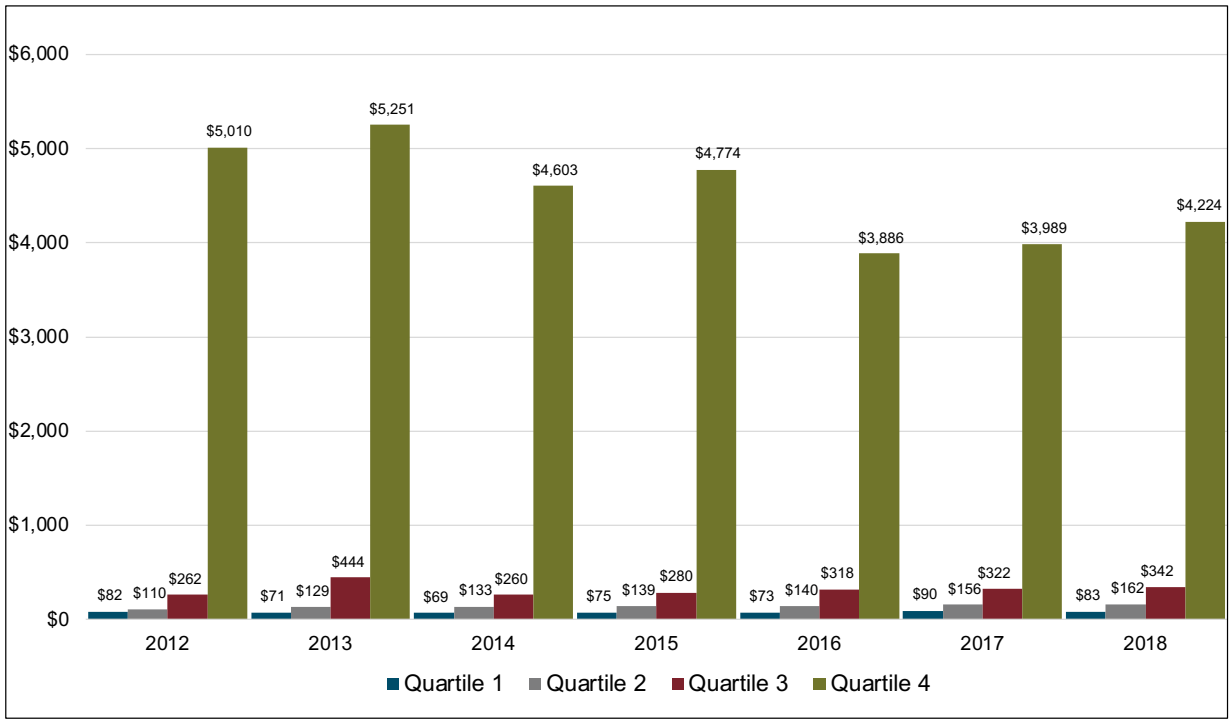

***Figure 4**: Size of university research expenditures (in millions USD) by quartile*

A key observation is the stark difference in the size of the research expenditures of institutions in quartile 4 versus those in quartiles 1, 2, and 3. Institutions in quartile 4 accounted for 91.69% percent of the total research base in 2012 and 87.80% of the total research base in 2018. While this appears to be a signficant decrease, the research expenditures of quartile 4 are greater by seven to ten times the sum of the research expenditures of institutions in quartiles 1, 2, and 3, underlining the outsized difference between institutions in quartile 4 versus all other quartiles.

Research expenditures per invention disclosure were the greatest for quartile 4 institutions, averaging about $2.9M per invention disclosure, and lowest for quartile 1 institutions, which averaged about $1.5M per invention disclosure (Figure 5). Institutions in quartiles 2 and 3 averaged about $2.4M per invention disclosure. It is not possible to account for these differences without further analysis of the nature of the institutions and the nature of the invention disclosures.

According to this data, one would be led to believe that research at smaller institutions generates new invention disclosures more efficiently. However, the higher rates of invention disclosures per million dollars of research may be attributable to many factors and warrants additional study. These include the

awareness of institutional technology transfer capabilities, the success of the TTO, support of the TTO by academic administration, and the presence (or lack) of a local innovation ecosystem.

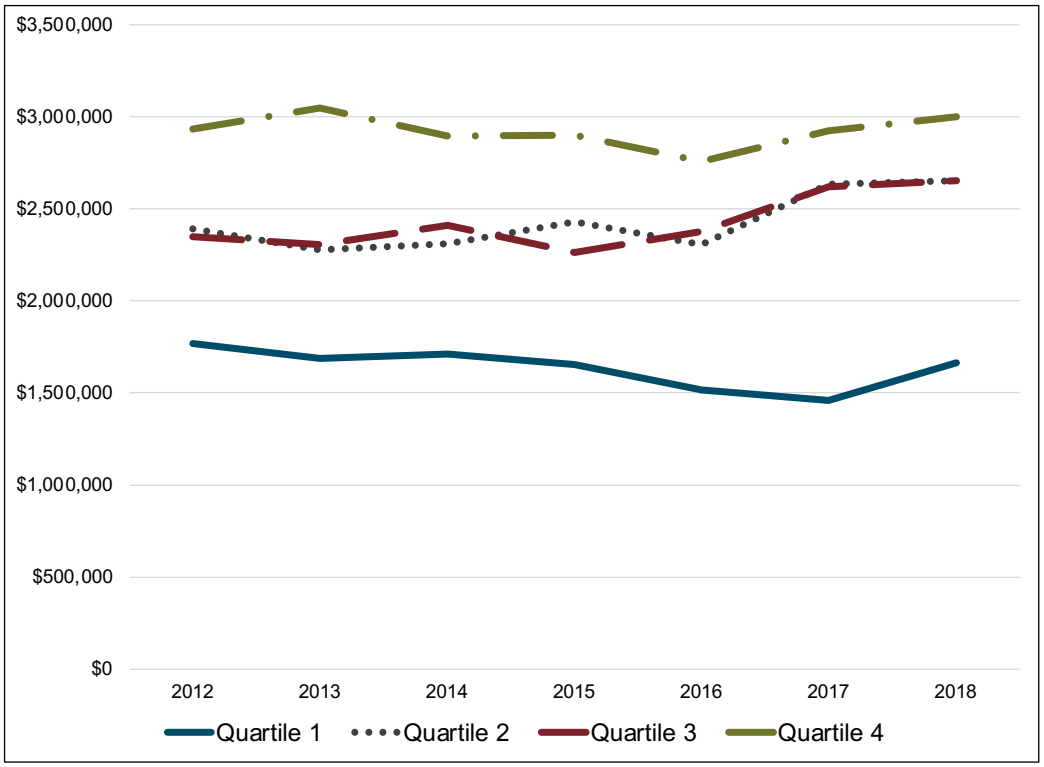

***Figure 5**: Research expenditures per invention disclosure*

As one would expect, total research expenditures were observed to have a positive high correlation between the number of licenses executed for all institutions in quartiles 1, 3, and 4 (Table 2). Quartile 2 institutions showed negative correlation between total research expenditures and licenses executed with a medium level of significance. The positive correlation between total research expenditures and licenses issues is to be expected, as higher levels of research expenditures lead to higher numbers of invention disclosures and therefore higher numbers of licenses executed.

Table 2: Impact of Research Expenditures on Licenses Signed

	Quartile 1		Quartile 2		Quartile 3		Quartile 4		All Institutions	
	EST	SGF	EST	SGF	EST	SGF	EST	SGF	EST	SGF
Total Research Expenditures	**0.379**	***	**-0.062**	**	**0.138**	***	**0.119**	***	**0.555**	***

2. TTO Staffing

The LAS provides a simple breakdown of staff responsibilities by full-time equivalency (FTE) which can be used to determine impact of staff on licensing outcomes. An analysis was done to compare total FTE, licensing FTE (LFTE) – staff having direct licensing responsibility – and those with non-licensing responsibility (NLFTE). Unfortunately, the LAS does not collect data on the specific responsibilities of NLFTE (i.e., patent management, marketing, business development and business/accounting functions). Therefore, it is not possible to analyze a direct correlation between specific types of responsibilities assigned to NFTEs and their potential impact on licensing.

a. Total FTE

The total FTE in TTOs increased from 2012 to 2018. The highest percentage increase in total FTE was in Quartile 2, which experienced 40% growth. The lowest percentage increase in total FTE was in Quartile 1 which experienced 3.8% growth (Figure 6). The growth of total FTE in each quartile tracks with the growth of the size of the research enterprise and the numbers of invention disclosures received. A potentially complicating factor is the determination of how much time is dedicated to licensing and non-licensing activities. For smaller offices, where one FTE may divide time between LFTE and NLFTE activities, the numbers may be more subjective. This subjectivity likely introduces variability in FTE counts. The data for larger TTOs, which typically have dedicated staff that are more discretely separated by licensing and non-licensing functions (such as market research, marketing, sponsored research agreements, and material transfer agreements), make the distinction between LFTE and NLFTE likely more objective.

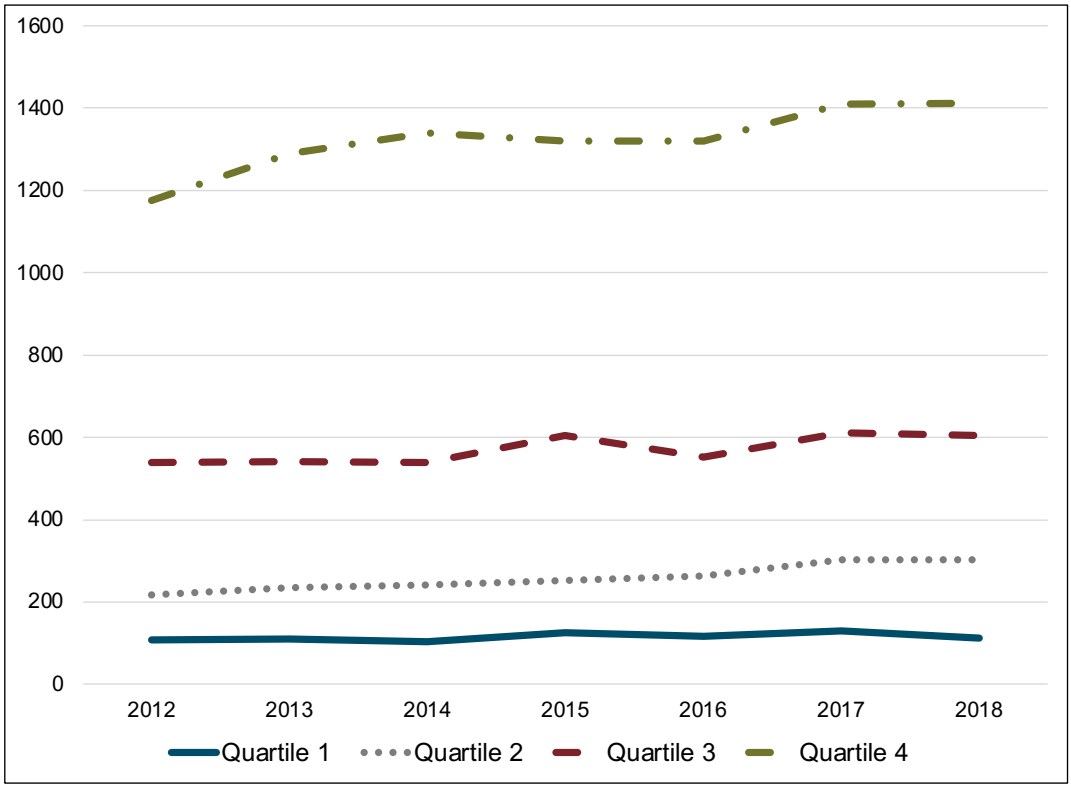

***Figure 6**: Total FTE per quartile*

b. Licensing FTE

The workload of a traditional TTO is driven by the "inputs" – generally, the number of new invention disclosures received. While the number of new invention disclosures increased over the period studied, the number of inventions disclosures per LFTE remained relatively stable in all four quartiles (Figure 7).

Traditionally, TTOs have sought to add additional LFTE to increase licensing output. LFTE were positively associated with number of licenses executed. This would be expected as greater number of LFTE would presumably lead to more licenses (Figure 8). These figures show that the numbers of licenses executed per licensing FTE increased marginally over the seven-year period for quartiles 2, 3, and 4 but decreased for institutions in quartile 1. While there has been a somewhat proportionate increase in LFTE (Table 1), the rate of licenses executed as a function of LFTE has not increased at the same rate. Finally, LFTE is positively associated with licenses executed with a high level of significance for all quartiles other than quartile 4 (Table 3).

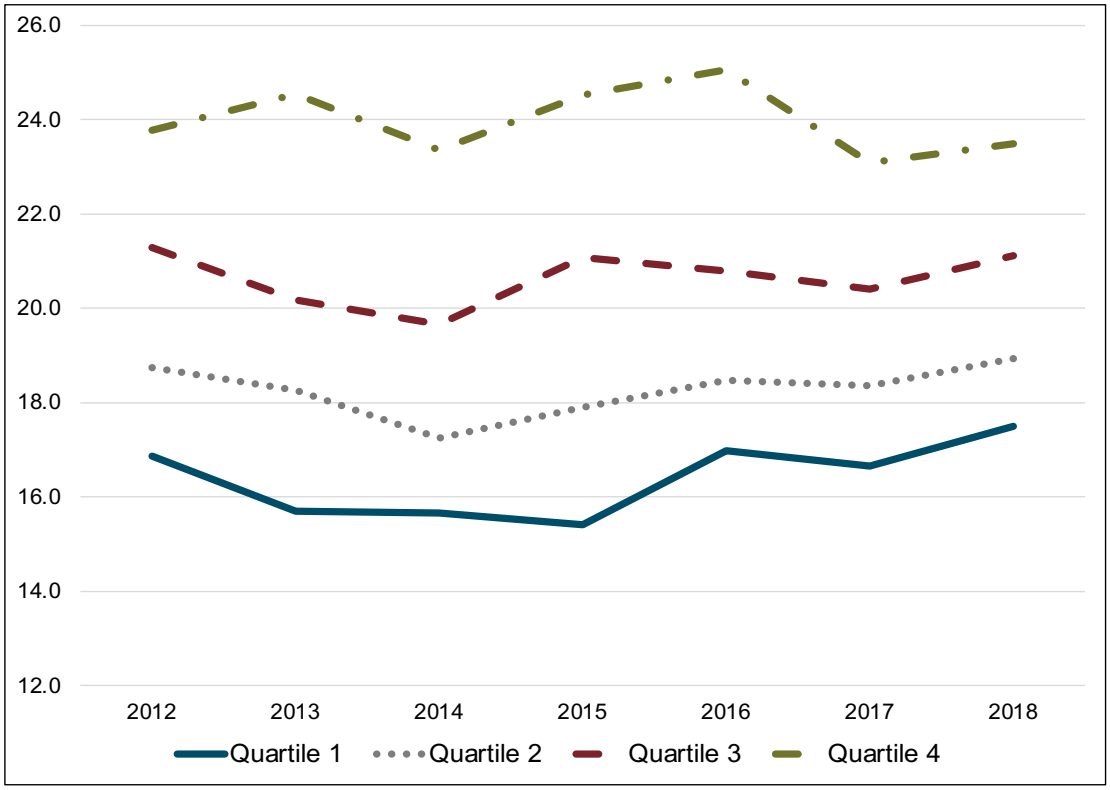

Figure 7: *Invention disclosures per licensing FTE*

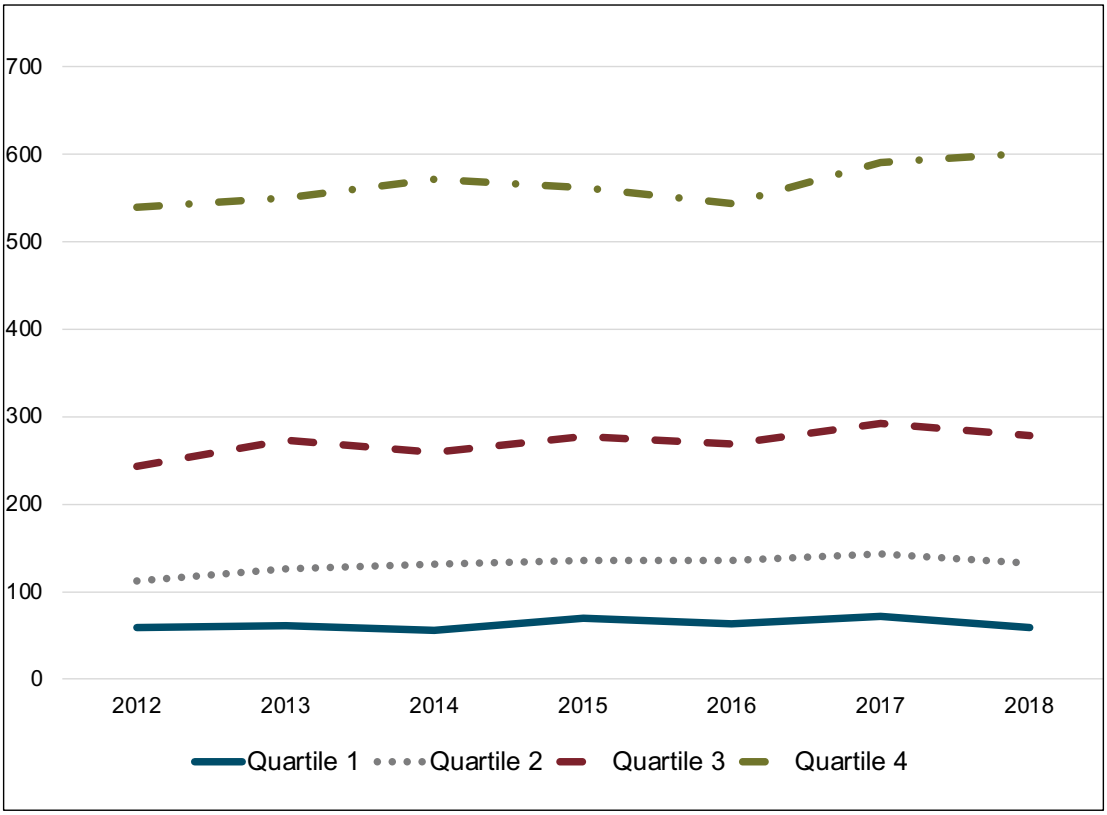

Figure 8: *Licensing FTE per quartile*

Table 3: Impact of Licensing FTEs on Licenses Signed										
	Quartile 1		Quartile 2		Quartile 3		Quartile 4		All Institutions	
	EST	SGF	EST	SGF	EST	SGF	EST	SGF	EST	SGF
Licensing FTEs	**0.494**	***	**0.266**	***	**0.091**	***	**0.020**		**0.150**	***

c. *Non-licensing FTE*

There are significant differences in the percentage of licensing versus non-licensing FTE between institutions in the different quartiles (LFTE constituted approximately 55% of total FTEs for quartile 1 institutions and about 40% for institutions in quartile 4 (Figure 9)). Institutions in quartile 2 showed the greatest change – LFTE decreased from a little over 50% to just over 40% over the seven-year time period. This was accompanied by a significant increase in the number of licenses per LFTE. Quartile 1 was the exception, where the number of licenses per licensing FTE actually decreased.

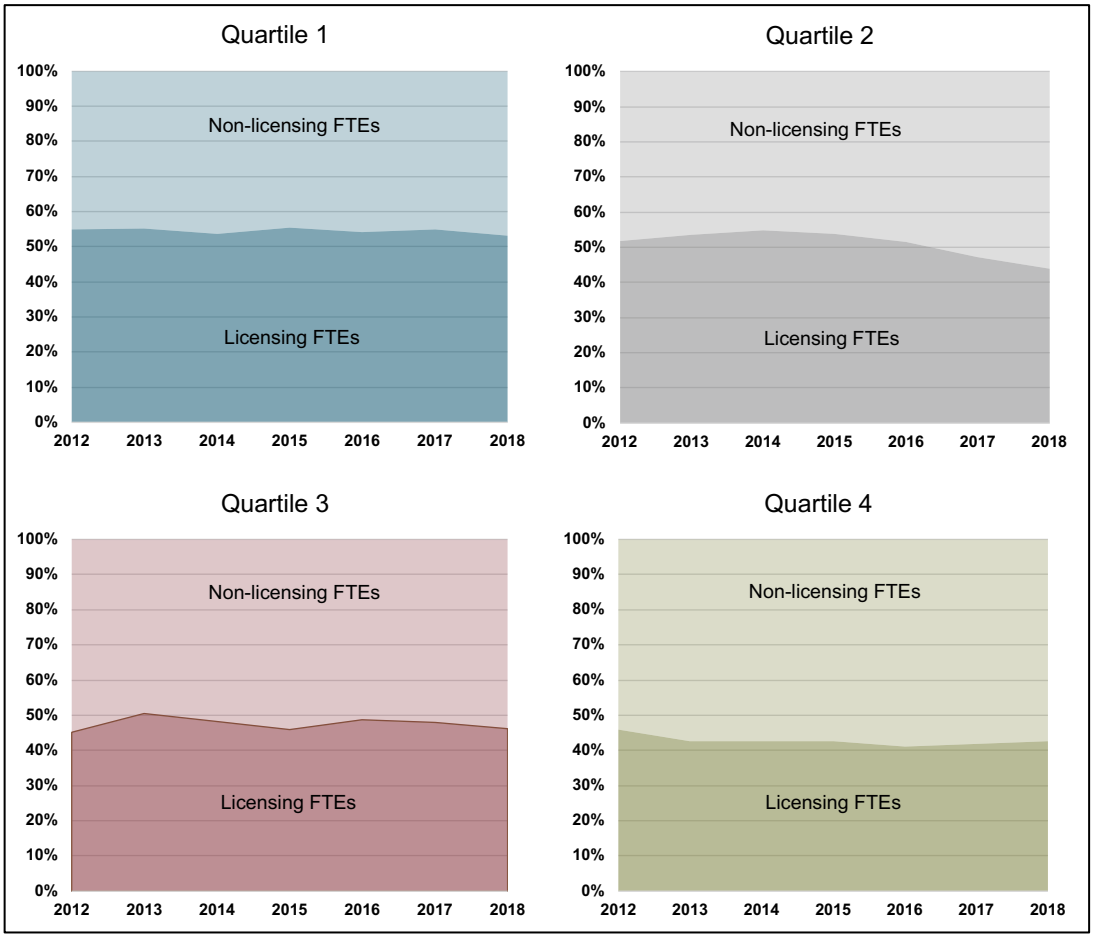

Figure 9: *Licensing versus non-licensing FTE*

The ratios of LFTE and NFLTE in the four quartiles shows the growth of the two in relationship to each other (Figure 9). The greatest growth of NFLTE occurred in quartile 2 institutions, while quartiles 1, 3, and 4 were relatively stable. Given the respective size differences in the research enterprise of the institutions in those quartiles one would expect for quartile 1 LFTE to have more non-licensing

responsibilities versus those in quartiles 3 and 4 where the offices have a relatively higher percentage of NFLTE.

Comparing the rate of licensing with the increase in NFLTE shows an extremely important trend, found in Figures 10, 11, 12, 13. For quartile 1 institutions the rate of licensing per LFTE (Figure 10) was relatively flat mirroring the relative flat growth of NFLTE. For quartiles 3 and 4 the rate of licenses per LFTE increased from 4.75 to 5.5 and 5.25 to 6.1 respectively (Figures 12 and 13). Quartile 4 institutions show a greater growth in NFLTE as compared to LFTE while the NFLTE growth in quartile 3 institutions was relatively flat. The greatest impact of growth of NFLTE (relative to LFTE) was in quartile 2 with a commensurate increase in the rate of licenses per LFTE from 3.75 to 5 (Figure 11).

The data suggests the addition of NLFTE to a TTO may have a larger positive impact on licensing outcomes, which may unburden LFTE and permit a more concentrated application of effort and experience on licensing functions. This is evidenced by quartile 1 data, as discussed below. Using the same metric of work input, the number of invention disclosures per NLFTE has dropped in three of the four quartiles (from 2012 to 2018, Quartile 1 dropped by 4%, Quartile 2 dropped by 26% and Quartile 4 dropped by 8.5%). Quartile 3 experienced a slight growth of 3% (Figure 14). This data supports a possible – and surprisingly non-obvious -- conclusion that any increase in licensing efficiency has been the result of TTOs adding NLFTEs.

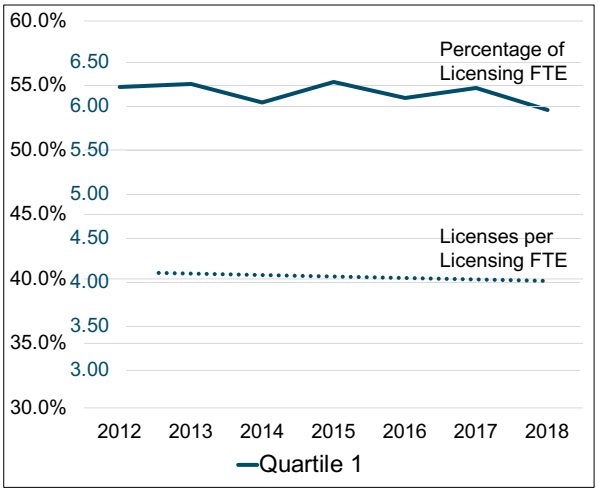

Figure 10: *Quartile 1 licensing FTE % and numbers of licenses per licensing FTE*

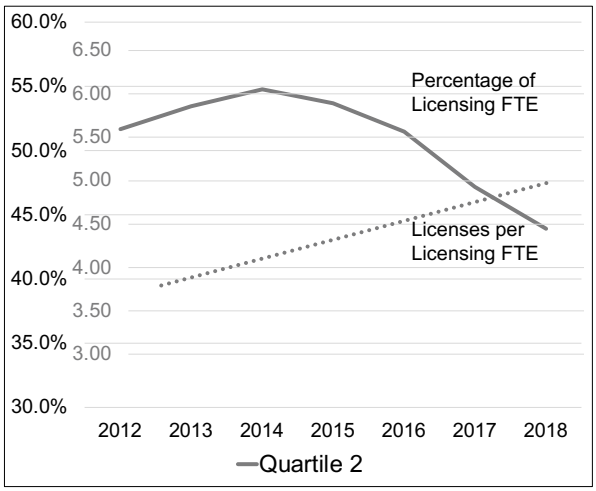

Figure 11: *Quartile 2 licensing FTE % and numbers of licenses per licensing FTE*

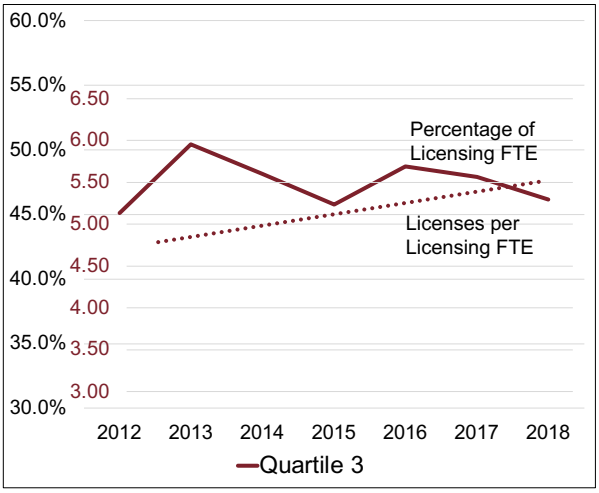

Figure 12: *Quartile 3 licensing FTE % and numbers of licenses per licensing FTE*

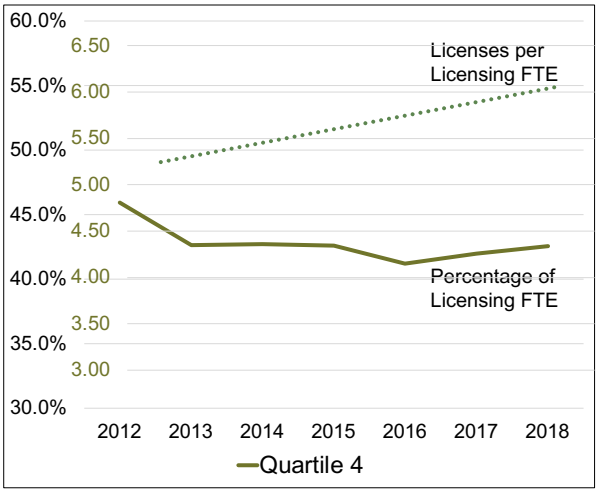

Figure 13: *Quartile 4 licensing FTE % and numbers of licenses per licensing FTE*

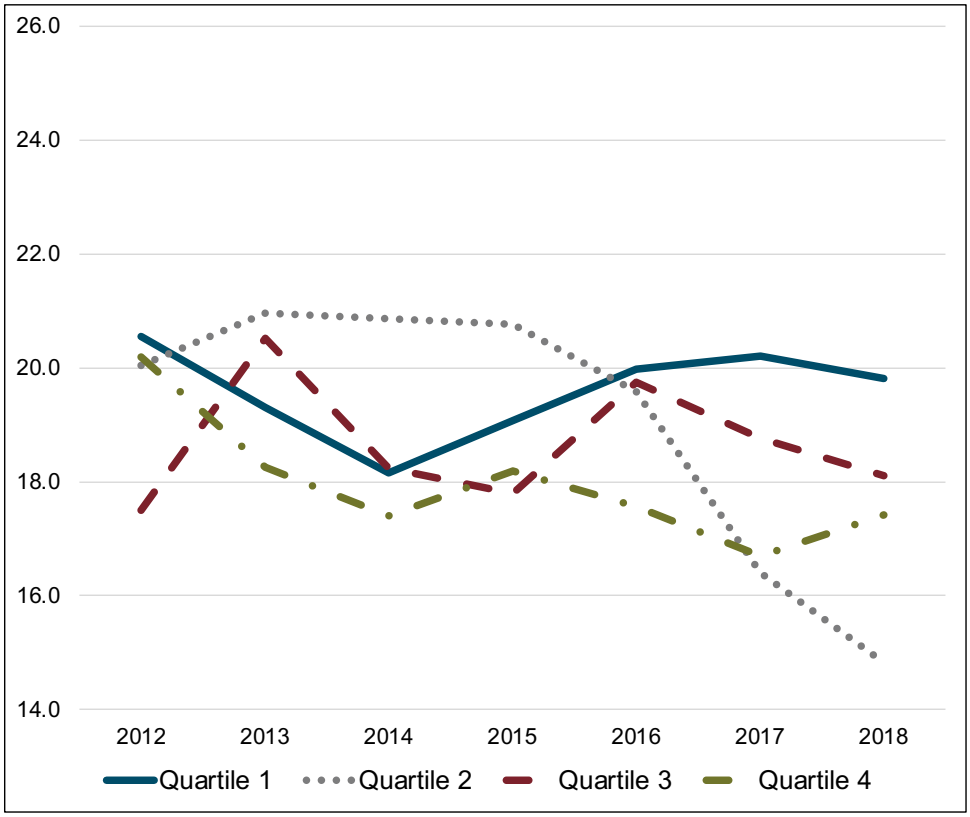

Figure 14: *Total invention disclosures per non-licensing FTEs*

3. Legal Fees

Patent protection is viewed as an essential element for the commercial attractiveness of a technology[17, 18]. The total legal fees incurred, and associated reimbursed and unreimbursed legal fees, have increased at a greater rate than all other basic metrics of TT (Table 1). In looking at total legal fees incurred, similar to research expenditures, quartile 4 institutions legal fees exceed the sum of legal fees for all institutions in quartiles 1, 2, and 3 (Figure 15). Legal fees for quartiles 1, 2, and 3 are substantially lower and in proportion to the sizes of the research expenditures of the institutions in those respective quartiles. Total legal fees incurred actually decreased for institutions in quartile 1 by 5.5%; and institutions in quartiles 4 and 3 show the greatest increases in legal fees expended (36.8% and 37.5% respectively). Additionally, the rate of unreimbursed legal fees varied greatly from 52% for quartile 4 institutions to about 68% for quartile 1 ~ about $121M per year on average for quartile 4 and $8M per year on average for quartile 1.

In order to obtain a better understanding of the resources committed by institutions to TTOs, a possible measure available from LAS may be legal fees incurred as a percentage of research expenditures (Figure 15). As a percentage, quartile 1 institutions total legal fees incurred were the greatest (approximately 0.7%) of the size of the research enterprise. Quartile 3 institutions were the most consistent over the reporting period at approximately 0.55%. There was a significant reduction of total legal fees incurred for quartile 2 institutions (from 0.7% to 0.54%) and an increase for quartile 4 institutions (from 0.51% to 0.64%). Given the respective size of research expenditures in the different quartiles, the respective absolute dollar amounts committed can represent a significant increase. Additionally, quartile 1 institutions showed variability in year-to-year commitment which may reflect a more ad-hoc allocation of funds for legal fees as opposed to a defined budget.

The percentage of unreimbursed legal fees by quartile – legal fees incurred but not reimbursed as a result of licensing the invention disclosure – varies greatly between the quartiles (Figure 16). Within quartile 4, institutions had almost 50% of their legal fees reimbursed. At the other end of the spectrum, quartile 1 institutions were successful in only recovering 33% of their legal fees. Likely reasons for the range in rate of reimbursement of legal fees include higher rates of LFTE and NLFTEs dedicated to

managing legal fees in institutions in quartile 4 versus quartile 1. Institutions in quartile 2 had a significant increase in the rates of unreimbursed legal fees, likely due to increased up-front investment in pursuing patent protection, whereas quartile 3 institutions showed a significant decrease in unreimbursed legal fees (Figure 17).

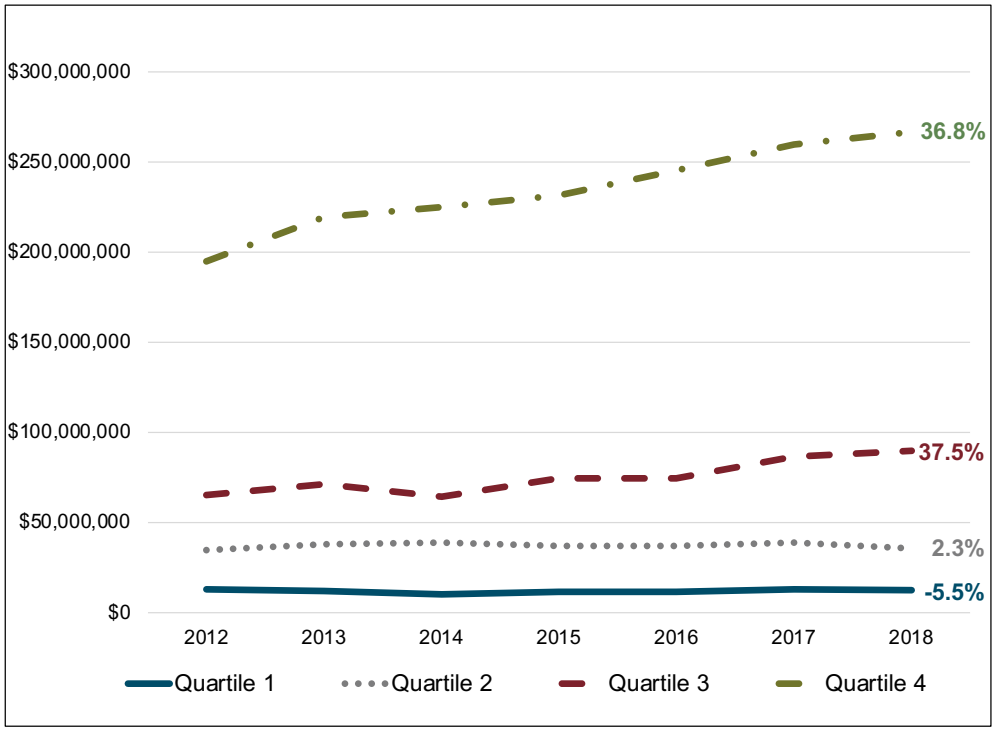

Figure 15: *Total legal fees incurred by quartile*

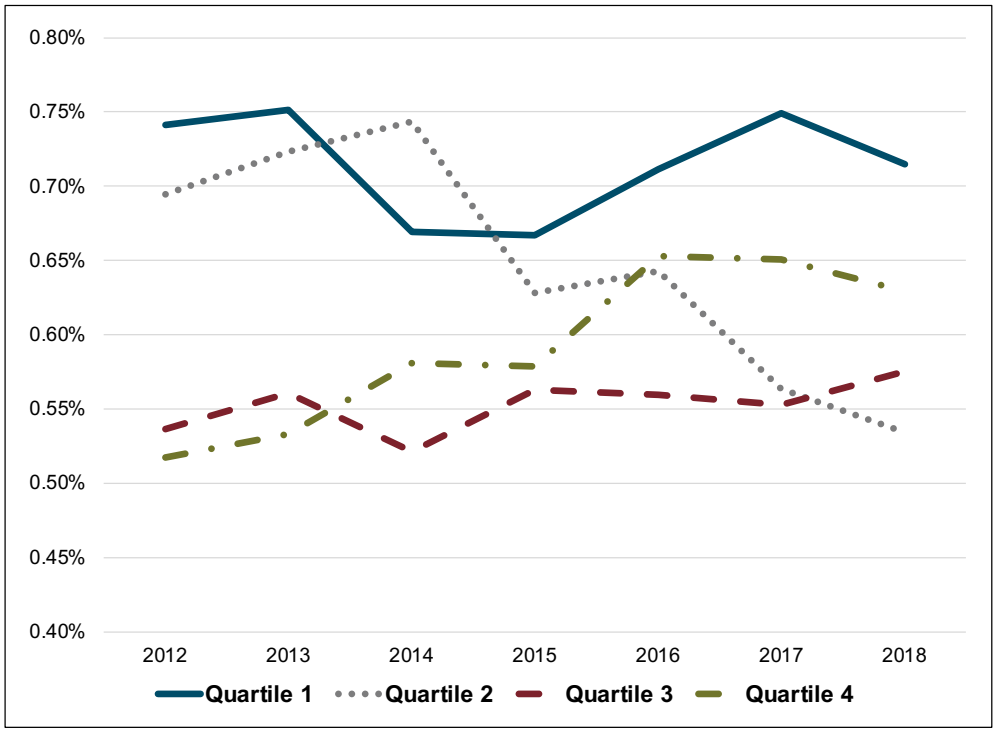

Figure 16*: Total legal fees incurred as a percentage of total research expenditures*

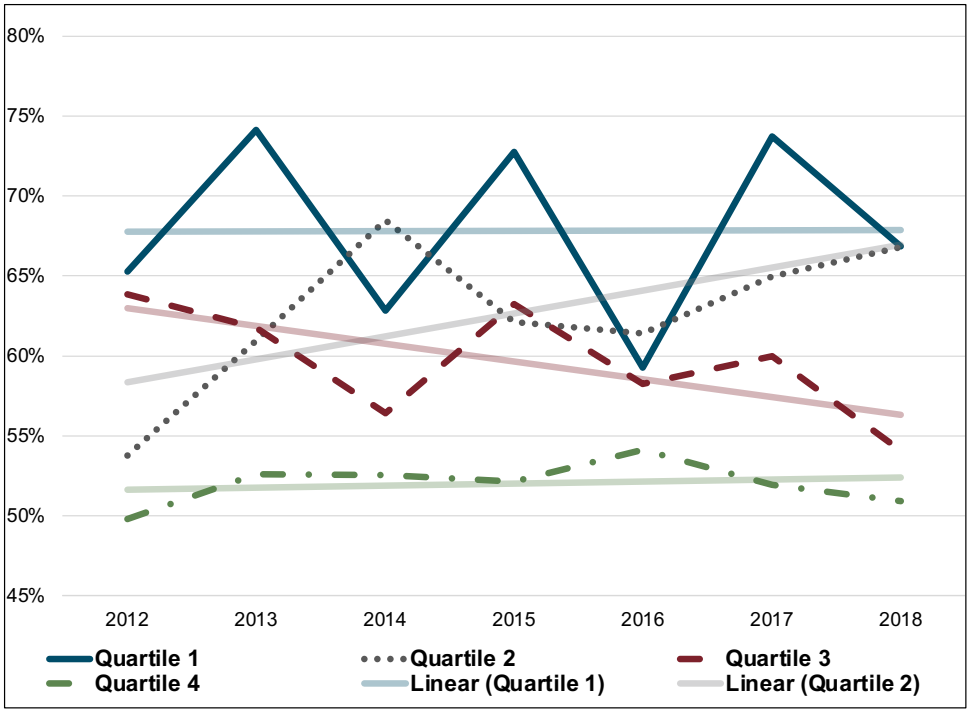

Figure 17: *Percent of legal fees unreimbursed by quartile*

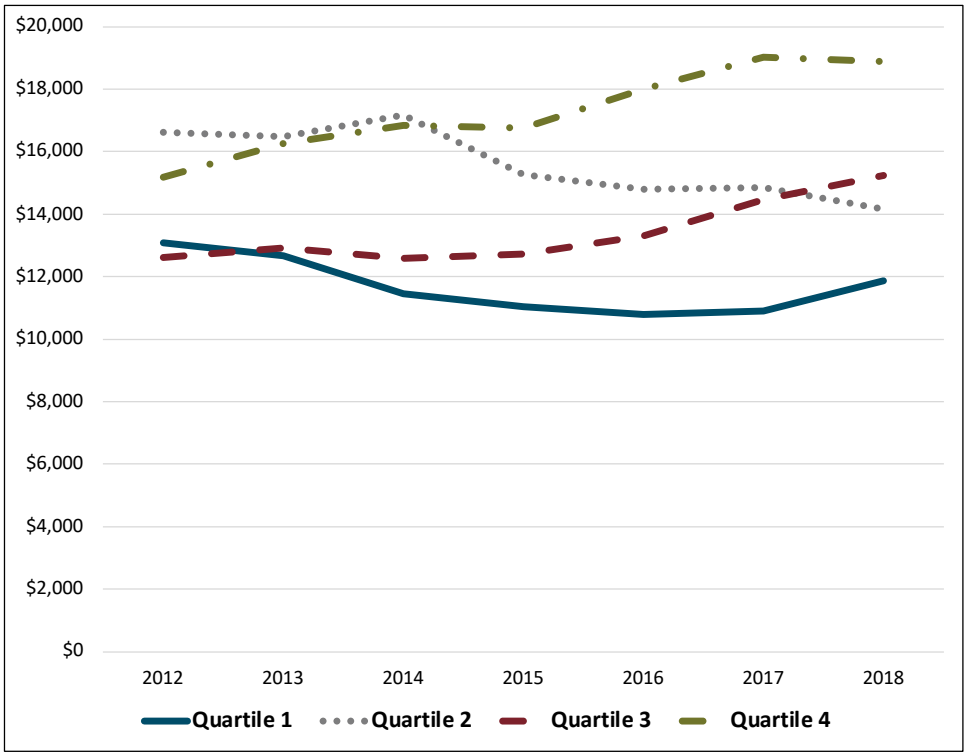

Figure 18: *Total Legal Fees per Invention Disclosure*

While institutions in quartile 4 were more efficient in having legal fees reimbursed, the total unreimbursed legal fees for institutions in quartile 4 amounted to over $135M for 2018 alone and to over $854M for the seven-year period used for this analysis. The trend for total legal fees incurred per invention disclosure received is decreasing for institutions in quartile 1 and 2 but increasing for institutions

in quartiles 3 and 4 (Figure 18). Notably, legal fees had the least impact on the number of licenses executed (Table 4).

Table 4: Impact of Total Legal Fees Incurred on Licenses Signed

	Quartile 1		Quartile 2		Quartile 3		Quartile 4		All Institutions	
	EST	SGF	EST	SGF	EST	SGF	EST	SGF	EST	SGF
Total Legal Fees Incurred	-0.250	***	-0.645	***	-0.022		-0.691	***	-0.472	***

DISCUSSION

TT is not a linear process. Invention disclosures received in any given year may not have a patent application filed until one or two years later with patents issued two or more years after the initial patent application is filed. Also, a license may occur anywhere between 6 months to 5 years after an invention disclosure was received. Data from the LAS therefore should be used to understand the trends over a period of time. These trends provide important information which can be used to assess individual institutions as well as the overall profession.

The overall trends for TT indicate steady increases in absolute numbers for all significant metrics with the exception of legal fees, which showed a disproportionate increase. That said, preliminary data is not definitively conclusive. This is due to a lack of data. Specifically, the LAS lacks information in key areas necessary to fully understand and optimize TTO efficiency, as follows:

- TTO structures
- Operational scope – both revenue and non-revenue generating activities
- Specific responsibilities of non-licensing staff – market research, marketing, administrative, intellectual property management, and startup formation
- Total budget and budget allocations of TTOs
- Other allocations of financial resources to activities such as technology gap funds and startup formation.

One of the starkest observations from the LAS data is the difference in the size of the research expenditures. Research expenditures for quartile 4 institutions are several times greater than the combined research expenditures of all institutions in quartiles 1, 2, and 3. However, this can be misleading, given that certain large university systems report aggregate numbers from all institutions in the system. An in-depth analysis of quartile 4 is warranted. Another notable observation is that it appears smaller research institutions generate invention disclosures more efficiently than larger research institutions with respect to research dollars per invention disclosure. But this may not be the case at all. It may be due to a greater desire of faculty at smaller institutions to engage in technology transfer, or it may be that larger research enterprises have a more diverse research portfolio that do not lend to commercialization. It is also possible that large research enterprises focus mainly on STEM fields while institutions with smaller research portfolios proactively seek invention disclosures from all fields. Without further research, it is impossible to know the reasons for this difference. Finally, a significant disparity was observed in staffing (growth of overall offices as well as relative growth of licensing versus non-licensing personnel), licensing (overall activity as well as numbers per licensing staff), and patenting (legal fees incurred and reimbursed legal fees) between institutions in the different quartiles.

While TTOs are not directly responsible for successful introduction of products to the market, they are responsible for building an environment that promotes commercialization activities – and, particularly, for the execution of license agreements that may lead to commercialization and revenue. The consensus among TT directors that licenses executed, faculty satisfaction, and the number of invention disclosures received are the top three determinants of a TTO's success is starkly juxtaposed with the perception that administration's top three determinants of TTO success were licensing revenue, faculty satisfaction, and

startups created. The difference may be attributable to the academic administration's lack of understanding of the licensing process and the licensee's responsibility for bringing a product to market, the pressure to generate revenue as seen by other institutions, or the need to support internal programs. It is unknown.

The one factor common between TTO directors and perception of administration priorities is faculty satisfaction. Based on anecdotal evidence, faculty satisfaction is driven by sincere, upfront, and transparent communication regarding patent protection, market need, manufacturability and cost, and the likelihood of finding a licensee. It can be argued that faculty satisfaction is the most important factor in creating an environment that promotes commercialization. All said, survey data indicate that institutional priorities for technology transfer success warrant further examination.

TTO directors identified that LFTE, legal (patenting) expenses, and startup support as their top three areas that positively impact their success. Intuitively, these are logical areas where resources should be allocated as they focus on functions of TTOs that impact licensing. However, it is clear from the data that investment in NLFTE seems to have the greatest impact on a TTOs success. Higher numbers of licenses per LFTE can be attributed to a greater focus on licensing by LFTEs as a result of off-loading responsibilities related to market research, marketing, intellectual property management, agreement administration, and other non-licensing function. Often, LFTEs have some or all of the experience and knowledge needed to complete the basic functions of an NLFTE such as, market research, marketing, negotiating sponsored research agreements, collaborative research agreements, material transfer agreements and confidentiality agreements (occurring more frequently in TTOs implementing a "cradle to grave" management strategies). When LFTE expends efforts in NLFTE areas, it diminishes their ability to focus on licensing.

It appears from the data that TTO directors have recognized this. Considering the importance directors place on executing licenses as a measure of success (as shown above), they have reacted by adding more NLFTE to their organizations to unburden their LFTE. In addition to increasing licensing numbers, NLFTE can be added at lower cost, since their salaries are usually less than LFTE salaries. Without additional data and analysis, it is not possible to assess which non-licensing functions would have the greatest impact on a TTOs success. Specifically, the functions of NLFTE personnel should examined, broken down by area of focus, e.g. finance, marketing, venture development, compliance, etc. It is possible this could be achieved by close examination of the institutions in quartile 4, since that quartile has the greater prevalence of NLFTE function-specific staff.

Legal fees, considered by TTO directors as second most important expenditure for a TTOs, are generally regarded as a cost of doing business in technology transfer – if you don't patent it you will not be able to license it. However, total legal fees incurred appear to have minimal impact on licensing success – and more importantly, there is a negative correlation between total legal fees incurred and licensing. Legal expenses are driven by several factors such as the early stage of research, the pressures of publication, the minimal market research performed, and the difficulty assessing potential customer need for early stage research. Taking this into consideration, it would be worthwhile to examine whether reallocation of portion of legal fees to NLFTE would have a positive impact on licensing outcomes. In fact, it may be possible to reduce legal fees by increasing certain categories of NLFTE in areas such as market research and patentability analysis. However, this is impossible to determine without a full examination of NLFTE by function and impact on licensing outcomes.

Based on the trends observed, it is clear that there are substantial variables which impact licensing outcomes. It is also clear that LAS data is insufficient to serve as an "apples to apples" comparison for institutions across all quartiles. That said, it is important to better understand all aspects of resource allocation that play a role in licensing outcomes – including unexamined allocations such as technology development ("gap") funding. Many variables remain to be examined in order to determine optimal balance of resource allocation for maximum licensing outcomes and additional research is needed. As such, efforts should be made to collect previously untracked data on the total resources that institutions allocate to technology transfer, how those resources are allocated internally, the relative impact of those internal allocations – all examined by quartile – to refine and improve both technology transfer and assure its continued positive impact on society.

METHODS AND MATERIALS

Data was compiled from the AUTM Licensing Activities Survey for the years 2012-2018. Institutions that did not have a complete data set, (i.e. critical multiple data points used for the study were not present), non-research performing institutions, and institutions with inconsistent results were eliminated from the data analysis. Remaining institutions were examined by quartile, with quartiles determined by total research expenditures. The number of institutions varied per year, from 156-164, due to elimination of institutions with incomplete data sets for any particular year and that all institutions do not consistently report numbers to the LAS every year. Factors analyzed were LFTE, NLFTE, research expenditures, and total legal fees.

Statistical analysis was conducted in three stages: 1) normalization of all factors corresponding to their standard deviations to scale one, respectively; 2) fitting a generalized linear model, which is desired for count responses, to estimate the coefficients of each factor; and 3) assessment and testing of the influences of the elements based on the estimated coefficients. The magnitude of coefficients statistically characterized the impacts of each element of the normalized data.

ACKNOWLEDGEMENTS

We wish to thank our team of advisors: Alexander Ducruet, University of Pittsburgh; Marie Kerbeshian, University of Iowa; Russ Lea, Seattle Children's Research Institute; Kirsten Leute, Osage University Partners; Andrew Maas, Louisiana State University; Keith Marmer, University of Utah; John Ritter, Princeton University; and Brian Shedd, University of Texas Permian Basin. We also thank Dr. Ellen Purpus for comments on the manuscript and Kristin Rencher for her work to compile and edit the manuscript. Finally, we thank the 48 directors who participated in our survey.

REFERENCES

[1] "Innovation's Gsolden Goose," The Economist, Technology Quarterly. December 14, 2002. https://www.economist.com/technology-quarterly/2002/12/14/innovations-golden-goose

[2] Pressman L., Planting M., Bond J., Yuskavage R., Moylan C., "The Economic Contribution of University/Nonprofit Inventions in the United States: 1996 – 2017" BIO, June 5, 2019, https://www.bio.org/sites/default/files/legacy/bioorg/docs/Economic_Contribution_Report_BIO_AUTM_JUN2019_web.pdf

[3] Pradhan A.S., "Evolution of Technology Transfer" December 2016, https://www.linkedin.com/post/edit/6214477521937932288/

[4] https://www.linkedin.com/pulse/evolution-technology-transfer-arundeep-s-pradhan-rttp/

[5] Perez-Pena R., "Patenting Their Discoveries Does Not Pay Off for Most Universities, a Study Says" New York Times Online, November 20, 2013, https://www.nytimes.com/2013/11/21/education/patenting-their-discoveries-does-not-pay-off-for-most-universities-a-study-says.html?_r=0

[6] Weis J., Bashyam1 A., Ekchian G. J., Paisner K., Vanderford, N.L., "Evaluating Disparities in The U.S. Technology Transfer Ecosystem to Improve Bench To Business Translation [version 1; peer review: 3 approved, 1 approved with reservations]"' F1000Research 2018, 7:329 https://doi.org/10.12688/f1000research.14210.1

[7] Arora A., Belenzon S., Patacconi A., Suh J., "Why the U.S. Innovation Ecosystem Is Slowing Down" Harvard Business Review, November 26, 2019, https://hbr.org/2019/11/why-the-u-s-innovation-ecosystem-is-slowing-down

[8] Kim J., Anderson T., Daim T., "Assessing University Technology Transfer: A Measure of Efficiency Patterns", International Journal of Innovation and Technology Management, Vol. 5, No. 4 (2008) pg 495-526. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.462.8805&rep=rep1&type=pdf

[9] Tseng A., Raudensky M., "Performance Evaluations of Technology Transfer Offices of Major US Research Universities", Journal of Technology Management & Innovation, Vol.9, No. 1, (2014), 93-102. http://dx.doi.org/10.4067/S0718-27242014000100008

[10] NIST Interagency Workgroup on Technology Transfer, "Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses", November 2012, https://www.nist.gov/system/files/documents/2017/05/09/MetricsPaper-FINAL-1-29-13.pdf

[11] Technology Transfer Tactics, "TTOs reach for new metrics to document their value", September 2009, https://techtransfercentral.com/reprints/ttt/909-new-metrics/

[12] Stoughton R., "Metrics for New – or Like-New – Tech Transfer Offices (TTOs)" Fuentek's Tech Transfer Blog, https://www.fuentek.com/blog-post/metrics-for-new-techtransfer-offices-ttos-intro/

[13] NIST Interagency Workgroup on Technology Transfer, "Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses", November 2012, https://www.nist.gov/system/files/documents/2017/05/09/MetricsPaper-FINAL-1-29-13.pdf

[14] Gordon P., "Controlling Costs of a Patent Portfolio: The Little Things Do Matter", Patent GC Blog, May 21, 2019, https://patentgc.com/ip-management-patent-processes-to-control-patent-costs/

[15] Kalanje C.M., Jaiya G.S., "IP and Business: Managing Patent Costs" Wipo Magazine Online, September 2006, https://www.wipo.int/wipo_magazine/en/2006/05/article_0010.html

[16] Abrams I., Leung G, Stevens A., "Is it all about the money? How are US Academic Licensing Offices Tasked and Motivated?", https://www.wpi.edu/sites/default/files/docs/Offices/Intellectual-Property/How_are_US_Academic_Licensing_Offices_Organized_Tasked_Financed_and_Motivated_--_Final.pdf

[17] Litan R., Singer H., "Unlocking Patents: Costs of Failure, Benefits of Success", Economist Incorporated, 2014, http://walkerinnovation.com/wp-content/uploads/2015/02/Litan-EI-Inc-Study-November-2014.pdf

[18] Launch Solutions Blog "The Value of Patents in Your Marketing Strategy", https://www.launchsolutions.com/blog/bid/352294/The-Value-of-Patents-in-Your-Marketing-Strategy