International Journal of Engineering and Technology Innovation, vol. 4, no. 4, 2014, pp. 193-212

Performance Assessments of Technology Transfer Offices of Thirty Major US Research Universities in 2012/2013

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Received 27 February 2014; received in revised form 01 May 2014; accepted 29 May 2014

Abstract

The activities and performance of thirty major universities technology transfer offices (TTOs) selected from major US universities are quantitatively assessed and compared. Six leading metrics, including TTOs' revenue, as well as quantity of invention disclosures, patent applications, patents granted, licenses signed, and startup companies launched, are used to develop a single overall performance metric (OPM) for representing the performance of the TTOs. The OPM are then evaluated for each of the thirty universities and their OPM scores are compared to each other to establish the reliability and effectiveness of a comprehensive OPM. A patenting control ratio (PCR) is also calculated to guide a TTO in setting its patenting strategy and procedures. These two metrics should be able to provide a comprehensive overview of how good is the TTO of a university as compare to those of its peers and, even more importantly, how the program fares globally.

Keywords: commercialization, innovation disclosure, license, patent, performance, startup company, technology transfer, university

1. Introduction

In response to the economic malaise of the 1960s and 1970s, a broad range of U.S. federal initiatives resulted in laws during the 1980s designed to remove barriers for new technology development and to foster technology transfer to industry [1-3]. As indicated by many investigators, these new laws permitted market forces to operate and shaped the dynamics of technology transfer. Among them, the Bayh-Dole Act (the "Act") of 1980 is considered one of the most influential pieces of legislation to impact the area of university technology transfer [3, 4]. The Act was designed to promote interaction between academia and the private sector. The Act provides for university ownership of intellectual property (including patent, copyright, material, and others) arising from government-funded research, with the express purpose of encouraging commercialization of this intellectual property through licensing or cooperative ventures between the university and industry.

Since a large portion of U.S. university research is funded by the federal government, university policy regarding technology transfer must be consistent with the law set forth in the Act. The mandate of the Act is that federally funded inventions should be licensed for commercial development for the public interest. Also, some portion of royalties from the invention must be shared with the inventors and must fund further research. To implement these mandates, almost all US

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research universities have established technology transfer offices (TTOs), which play a major role in transferring university-based intellectual property to the private sector for commercialization [5, 6]. As a result, in the past thirty years, universities in the U.S. have greatly expanded their technology transfer efforts, resulting in a boom in technology transfer activities in terms of the numbers of patents granted to, and licenses signed by, the universities [4, 7].

Recently, because of the growth of Internet commerce and advances in digital, information, and biotechnology technologies, a broad range of entrepreneurial companies have been formed. The subject matter in technology transfer have also changed greatly as compared to twenty or thirty years ago. For example, the patentability of biological materials and biomedical research tools as well as the technology transfer of digital data and computer software are recently becoming hot issues in technology transfer [8-10]. Given these changes, it would be useful to assess the recent activities and performance of university technology transfer and what the influence of the current technology environment on the performance is.

Consequently, the purpose of the present article is to quantitatively assess the recent activities and developments of university technology transfer for thirty major US research universities. Six leading performance metrics are selected. These six metrics can be directly used to measure the TTOs' performance but are not directly related to university research achievement, more specifically research expenditure, as demonstrated by a series of correlation analyses of the data provided by these thirty universities. Using these six metrics, an overall performance metric (OPM) is developed to measure the overall accomplishment of the TTOs. The methodology adopted to develop this metric weights the accomplishment and associated difficulty and limitation for each metric selected, in order to provide more comprehensive metrics. The OPM are evaluated for each of the thirty universities, and the resulting scores are compared to each other to demonstrate its simplicity and comprehensiveness. A patenting control ratio (PCR) is also developed for each of the thirty universities to judge the properness of the patenting strategy adopted by its TTO and to gauge whether or not its patenting budget is being well spent. Finally, the concluding remarks are given to summarize the results and to a perspective of the future of university technology transfer.

As discussed later and shown in Fig. 2, the technology transfer process is typically a series or sequential process, involving many key steps or activities. Inherently, there are time-lags among these steps. The time-lags can vary by institutions and technology areas as well as the local and global economic and industrial environment. For example, the institutional factors that can influence the time-lags can be the goals, efforts, strategies and types of an institution concerning technology transfer. As a result, statistical methods or mean values are adopted to estimate these time-lags [11, 12]. In the present performance evaluation, since, the metrics selected from these key steps are based on a specific year considered, i.e., no time-lags being considered among the metrics selected, the overall metrics evaluated represent not only the performance of the specific year considered but also provide a measure that can migrate to gauge the future health or performance of TTO. The time span and the associated magnitudes of the migration effect are certainly dependent on the specific time-lags associated with each metrics or step [11, 12]. Consequently, the overall metrics developed not only represent the performance of the specific year considered but also have influence on the subsequent years, where the influence can last for several years as indicated by Heher [11] and Kim & Daim [12].

In many respects, the overall metrics presently developed are similar to student's GPA (grade point average), which is used to measure the student's academic performance in a specific year. The GPA for a specific year can also affect the student's performance in the subsequent year. Since many courses in school are sequential in nature, the level of the understanding (or performance) of a prerequisite course can affect the comprehension of the student to the subsequent course, and, in turn, affect the student's performance of the subsequent GPA.

2. University Technology Transfer Office and its Activities

In addition to managing the increasing technology transfer activities required by the Act, university TTOs have become increasingly important, given concerns regarding universities' desire to maximize the returns on their intellectual property, especially on the patents they own.

2.1. Missions and technology transfer

In general, a TTO in a university serves the faculty, staff and students to manage activities relating to commercializing intellectual property, and complying with regulations mandated by the Act [11]. In commercialization, the intellectual properties, especially patents, are licensed by universities to commercial organizations that should commit to further develop these early-stage technologies into commercial products. As a result, the typical TTO's mission includes: a) protecting the university's intellectual property, b) facilitating communication between faculty and industry, c) streamlining technical transfer processes by complying with mandates by the Act, federal patent law, and university licensing policy, d) encouraging an entrepreneurial environment among faculty and students, and e) managing patent & license-related expenses while working under a budget.

In many universities, the missions of TTOs are beyond the mandates of the Act and also contribute to the primary roles of a university, i.e., education, research, and public service. For example, some TTOs help fulfill the "research and education" missions by promoting and managing research partnerships among government, university, and industry. These collaborations may provide universities with new research and educational opportunities that encourage scholarship, research assistantships, and internships to train and supply highly skilled and knowledgeable students to industry. Furthermore, since the primary goal of a TTO is to ensure that university inventions are diligently developed into products and services that are ultimately made available to the public, these activities are also consistent with a university's role of "public service".

Consequently, the activities of university technology transfer can also include, for example, the following [12]: a) providing connections between inventors and users of new knowledge through professional meetings, conferences, seminars, industrial liaison programs, and other venues, b) promoting sponsored research projects involving business-academia agreements, c) initiating multi-firm arrangements, such as university-industry cooperative research centers, and d) delivering seminars for advancing an entrepreneurial environment for faculty and students. These technology-transfer activities often operate in a complementary fashion, offering significant contributions to TTOs' missions.

2.2. Organization and funding of technology transfer office (TTO)

It is not known exactly how many universities are engaged in technology transfer activities. One indicator is that over 230 U.S. universities and nonprofit research institutions are represented in the Association of University Technology Managers (AUTM) [13-14]. Among those universities that are active, one can observe a variety of structures and sizes. The organization structure of a TTO can vary from institution to institution, due to the differences in culture and composition. Based on a survey of 126 universities and 39 other nonprofit organizations, Abrams et al. [15] reported that a total of 86% (=142) of TTOs were organized as units of the institution and the remainder, 14% (=23), were separate corporations. Of the 23 offices organized as independent corporations, all but one were associated with public institutions. Since public universities are governmental entities and so are subject to certain contractual constraints, it could be advantageous to assign ownership of, and responsibility for, licensing their intellectual property to a research foundation that is an independent 501(c)3 non-profit organization [16], which is not subject to the legal constraints of a governmental entity.

They also found that most TTO directors ultimately report to a Provost (academic line), a Vice President (administrative line), or an independent Board. Reporting through a Vice President is somewhat more common, with a small proportion reporting directly to the President or Chancellor. The structure of a TTO is frequently a functional organization that uses the principle of specialization based on function or role, and a typical organization chart for a TTO within a university is shown in Fig. 1. In a functional organization, the specific services and decisions are delegated to specialized persons or units, which can permit university-generated intellectual property to translate more easily into marketable products for the benefit of the university as a whole.

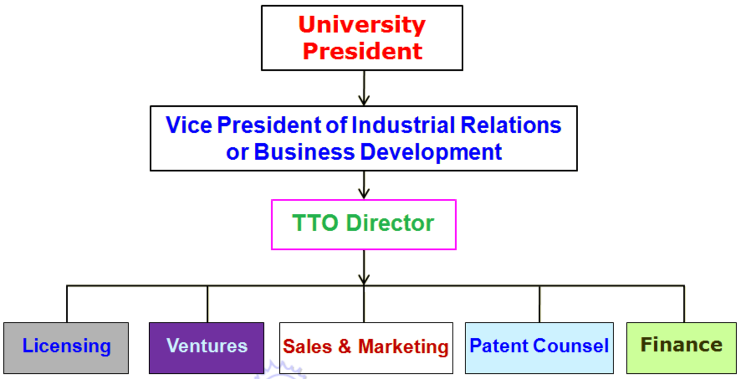

Fig. 1 Organization chart for typical technology transfer office in U.S. university

The typical procedures for technology transfer are: disclosure of inventions, record keeping and management, evaluation and marketing, patent prosecution, negotiation and drafting of license agreements, also the management of active licenses. The five branches of the TTO shown in Fig. 1 represent the five major tasks in technology transfer: patenting, licensing, capital investment (venture), sales & marketing, and finance management. The patent counsel is also responsible for enforcement of patents and licenses.

Based on a survey of 114 institutions, Abrams et al. [15] reported that the average annual budget or expenditures for a TTO is US$1,858,206, where 53.3% of the budget is operations and 44.2% covers patent expense. The remaining 2.5% is not specified. Each TTO, on average, employed 8 staff members, where 4.4 FTEs (Full-time equivalents) are professional and 3.6 FTEs are support staff. 60% of the institutions had separate patent and operating expenditures, while the other institutions were given a combined budget, implying they had the flexibility to spend their budget between the two categories as they saw fit.

2.3. *Typical invention disclosure procedures*

As discussed earlier, on average, 44.2% of the TTO budget is for patent applications. As a result, processing invention disclosures for patenting is a critical step for technology transfer and an important task for a TTO. The major steps in patenting are: preparing documents for invention disclosure, maintenance and management, evaluation and marketing, and patent prosecution.

The disclosure document is typically prepared by the inventor and submitted to the TTO to notify it of an innovation. It contains information about the invention, the inventors, funding sources, and other information such as related publications, likely candidates for licensing, etc. The invention must be described in enough detail that someone skilled in the art could understand and make the invention. The disclosure is reviewed by the licensing staff to make a preliminary recommendation or decision about ownership and the invention's potential commercial value and patentability. Then the disclosure application, with the staff's recommendation, is submitted to a university committee for the final recommendation and decision. The options for the committee's review and decision can include: a) Accept, TTO filing a provisional or regular patent application and initiating a marketing plan; b) Waive, delegating the right to the sponsoring agency or inventor; c) Incomplete, requiring further input for the disclosure; and d) Decline, returning the application for other considerations. The typical criteria adopted for patent review can include: a) interested potential licensees; b) US and foreign patent opportunities; c) potential market size, penetration, and returns to the university; d) complications; and e) enforceability. Also, the TTO takes action to ensure that the newly disclosed intellectual property is handled in compliance with federal and university policies. At this stage, the TTO may also begin finding inventors and talking to venture capital. The whole patenting process is summarized in the first five steps (green or shadowed blocks) shown in Fig. 2, where the major players associated with each step are also indicated. If any step ends in a red-colored decision shown in the figure, the patenting process is terminated. Suggestions are normally provided for reconsideration.

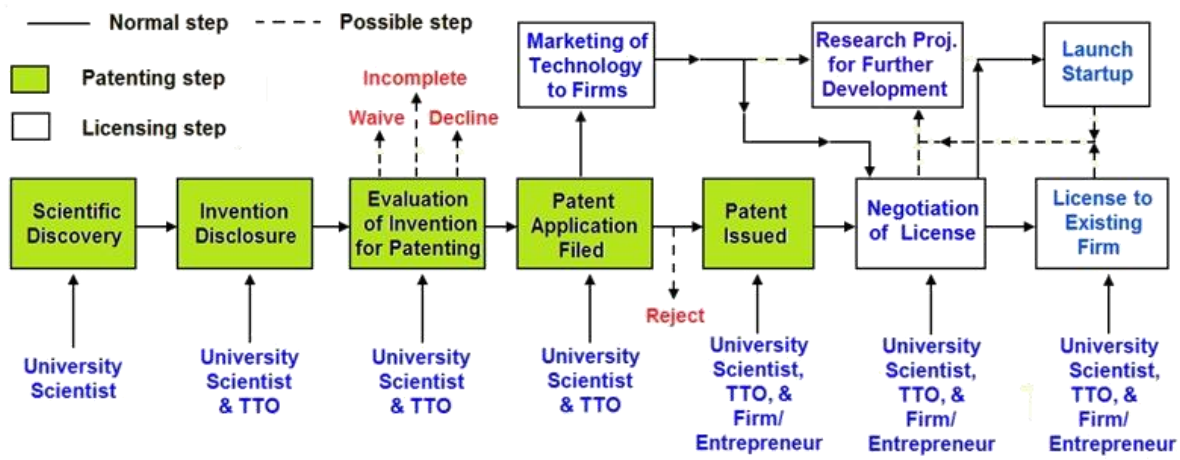

Fig. 2 Typical processes of technology transfer in university

It is understood that one of the fundamental principles of academic research is the right of individual inventors to make independent judgments regarding the timing and venue for the publication of data generated in their research in journals, other written media, or through oral presentation at public meetings. At the same time, publication of the details of an invention prior to filing a patent application can result in the loss of patent rights in most countries. The U.S. is an exception, since it permits an inventor to obtain a patent if a patent application is filed within one year of the date of publication which first disclosed the invention. In addition, the U.S. permits provisional patent applications which allow the extremely quick and inexpensive filing of a patent application as a one-year place holder for a subsequent non-provisional patent application. Nevertheless, very often patenting decisions by TTOs must be made quickly.

The advent of provisional patent applications in 1994 has helped TTO's by enabling filing of a low cost provisional application without overburdening the patent application cost in the first filing. The provisional application establishes an early filing date, but the application does not mature into an issued patent unless the applicant files a regular, non-provisional patent application within one year. Because no examination of the patentability of the application in view of prior art is performed, the USPTO (United States Patent and Trademark Office) fee for filing a provisional patent application is significantly lower (US$130 as of April 2013). It is expected that during the one-year period after provisional filing, the TTO can find inventors to cover the cost for a regular patent application.

The recent Leahy–Smith America Invents Act (AIA), which became effective on March 16, 2013, represents the most significant change to the U.S. patent system since 1952. The law switches U.S. rights to a patent from the present "first-to-invent" system to a "first inventor-to-file" system for patent applications. The AIA also expands the definition of prior art (such as including foreign offers for sale and public use) used in determining patentability. Making a disclosure before a patent filing is therefore extremely risky. It can no longer antedate or swear behind another's work, so one should make sure that any patent application is filed as early and as completely as possible. The AIA may bar a patent if any of the following occur before the effective filing date (EFD): a) invention described in a printed publication, b) invention placed in public use, c) invention placed on sale, d) invention otherwise made available to the public, or e) invention described in issued US patent or published US patent application naming another inventor and having an EFD before the EFD of the relevant patent or application.

As indicated by Fox [17], the AIA would simplify the application process and bring U.S. patent law into better harmony with patent law of other countries, especially in the European Union, most of which operate on the "first-to-file" system. Proponents also claimed it would eliminate costly interference proceedings at the US Patent and Trademark Office and reduce U.S. applicants' disadvantages in seeking patent rights outside of the United States. On the contrary, opponents, including Nesheim [18], argued that the AIA would prevent startup companies, a potent source of inventions, from raising capital and being able to commercialize their inventions. Typically, only after receiving investment capital would an inventor have a sufficient conception of the invention and the necessary funding to file a patent application. Before receiving investor funding, the inventor must have already conceived the invention, proven its functionality, and done sufficient market research to propose a detailed business plan. Investors will then scrutinize the business plan and evaluate competitive risk, which is inherently high for startup companies as new entrants into the market. Critics expressed concern that venture funding now will be diverted to less risky investments.

2.4. Major considerations in licensing

After the patent application is filed, the TTO then markets the invention to industry and seeks licenses to get industry participation and investment in the technology. The TTO also needs to have its patent filing and prosecution costs reimbursed so these funds can be recycled into additional patent filings. If the patent fails to issue, the license can be terminated. As part of a TTO's marketing of the invention, a non-confidential summary is sent to companies that are likely to be interested. If a company expresses interest, it will be asked to sign a confidentiality or nondisclosure agreement (to protect patent rights) prior to receiving confidential information from the university. If the patent is granted and the company continues to be interested after reviewing the confidential information, an agreement with the company is negotiated. This can be a letter of intent, an option, or a license. Before serious negotiations begin, the potential licensee must demonstrate that it has the technical, financial and marketing capabilities to develop the invention into a product or service and to bring it to market. The license agreement should ensure the company's commitment and to provide a fair financial return to the university's contribution.

A typical licensing process includes the last five steps shown in Fig. 2 (the white or non-shadowed blocks). The process may also involve further technology development and startup company launching. Again, the major participants for each step involved are also shown.

The licensing of university intellectual property is the major revenue source for university technology transfer. License fees and royalties are determined by lengthy negotiations. Fees and royalty rates are rarely large because most of the technology is in early stages and risky, thus requiring additional research and considerable investment before product development can begin. Consequently, finding companies willing to take the risk can be challenging, except for inventions with clear commercial applications and large potential markets. For this reason, traditional methods of technology marketing, such as advertising the invention, publishing lists of technologies available for licensing, or using Internet listing services, have had limited success in finding licensees for university patents.

A license to a patent can be exclusive, partially exclusive, or nonexclusive. An exclusive license, which is granted to one company only, can increase the incentive for the company to make the risky investment in development, since the patent can protect the company from competition. Few companies may be willing to enter into a nonexclusive license; however, if more than one qualified licensee has requested a license, the license may also be divided by field of use. Also, although a small or startup company may fail more often than a larger licensee, a small company licensee may be the best choice because of its motivation and enthusiasm to carry a special product through to commercialization. In some cases, licensing to a startup could be the only choice because no large companies are interested in the invention. Often, the inventor may also be able to play an active role in advising, or perhaps even assuming a management role in, a startup company to facilitate further development and commercialization. A research agreement can often be negotiated to continue work on the invention at the university.

Universities generally apply the same policies and procedures to all inventions made at the institution, regardless of sponsorship. In the case of federally funded inventions, under the Act, all licenses must acknowledge that the federal government also has a license for government purposes. If it is an industrially-supported invention, the sponsoring company is frequently granted the first opportunity to obtain a license to commercialize the invention. If joint government and industry funding is involved, the company's rights are subject to the institution's obligations to the federal government. In some government programs involving active industry collaboration, the government may specify the company's rights in resulting inventions and related intellectual property. Otherwise, the TTO needs to negotiate the specific terms related to patent rights.

3. Correlation of Research Expenditure to Performance Metrics

In this section, the performance metrics are selected, and data for the metrics selected are collected for thirty major research universities. Correlations are performed to assess the effects of research expenditures on these performance metrics. As mentioned earlier, the major incentive of the Act is to provide universities ownership of intellectual properties generated from university projects funded by federal agencies. Federal research funding, in fact, acted as the original source or driving force for university technology transfer [19, 20]. Thus, the significance and impact of research funding on university technology transfer, especially on the selected metrics, should be understood. It is noteworthy that research expenditure is the most important metric in determining whether a university is a leading research university [21] and is the major driving force for a university to build its research reputation, which has been argued to be an influential factor for university technology transfer [22].

3.1. Selection of performance metrics and thirty major universities

The performance of university TTOs has been studied by many investigators, and a wide range of metrics has been selected to assess their performance. For example, Trune & Goslin [23], Rogers, et al. [19], Thursby & Thursby [24], Litan et al. [25], and Roessner et al. [26] suggested that license revenue is the most important outcome and performance metric for university technology transfer, while Rogers et al. [19] and Xu et al. [27] applied invention disclosures as an antecedent variable to measure achievement of TTOs, such as numbers of TTO licenses and startups. Based on the above mentioned studies [19], [23]-[27] and those by Anderson et al. [5], Abrams et al. [15], York & Ahn [22], Foltz et al. [28], O'Shea [29], West [30], and Kurman [31], the performance measure for a TTO can be quantified by the following metrics: a) TTO revenue, b) number of invention disclosures, c) number of patent applications, d) number of patents granted, e) number of licenses signed, f) number of start-ups formed, g) research expenditure of university scientists, h) expenditure of patenting activities, i) operation expenditure, j) number of new commercial products, k) employment and productivity growth of start-up partners, l) changes in stock prices of industrial partners, etc. The first six metrics are more frequently applied for measuring the performance or accomplishment of a TTO. In the present study, these six metrics are adopted for the quantitative evaluation of TTO performance for a wide range of major US research universities. It is noteworthy that among these six metrics adopted, TTO revenue is the resulted measure of the entire TTO activity discussed in the precedent section, while the remaining five metrics are respective outcomes of the five major activities (3 in patenting and 2 in licensing blocks) of the technology transfer process illustrated in Fig. 2.

Thirty major research universities, which are ranked by their annual TTO revenues and shown in Table 1, are selected for the TTO performance study. As shown, TTO revenues vary from a high of $161.7 million for Columbia University to $1.9 million for Arizona State University. The TTO revenue counted include income from licensing and royalty, reimbursement of patent expense and licensee legal fees, and extraordinary income, which can be non-recurring items such as sales of equity and payments resolving patent litigation cases. Frequently, upon execution of a license agreement, licensees normally reimburse the licensor or TTO for past patent expenses or initial administration and organization.

Among the 30 universities selected, 23 are from the list of the thirty universities with the largest R&D expenditures in FY2011, reported by US National Science Foundation (NSF) [32]. The 7 universities which are not on the NSF 30 list are chosen to allow the present study to have a broader geographic representation. Additionally, some of the universities on the NSF list which were not selected did not post all the technology transfer data required and did not respond to email requests from the authors.

Table 1 TTO performance metrics for selected major-research universities in FY2012 or FY2013

University	Revenue	In. discl	Pat. filed	Pat. issued	PCR [%]	License signed	Start-ups	OPM	R&D* expenditure	Year
Columbia	161.7	351	301	76	23.3	80	15	1.77	879[12]	2012
MIT	137.1	690	426	229	39.2	107	16	2.33	724[20]	2012
Princeton	130.0	106	130	31	26.3	19	0	0.96	193	2012
Northwestern	130.0	222	145	76	42.6	66	11	1.28	619[29]	2013
U Washington	77.0	462	182	61	19.0	209	9	1.64	1149[3]	2013
Stanford	76.7	504	285	201	51.0	137	17	1.76	908[9]	2012
Minnesota	45.7	322	115	59	27.1	75	12	0.94	847[13]	2012
Wisconsin	41.1	373	144	153	59.2	41	4	0.99	1112[4]	2012
UC San Fran.	37.3	227	71	35	24.3	35	7	0.61	995[7]	2012
Colorado	32.8	226	226	41	18.6	48	10	0.79	790	2012
Duke	24.6	225	113	50	30.5	123	6	0.82	1022[5]	2012
UCLA	22.7	343	236	74	25.6	34	13	0.88	982[8]	2012
Texas-Austin	20.3	169	71	40	33.3	17	3	0.43	632[28]	2012
UC San Diego	19.0	433	169	94	31.2	43	12	0.93	1009[6]	2012
Johns Hopkins	17.9	441	164	67	22.1	133	8	1.11	2245[1]	2013
Uni Penn	17.9	385	115	73	29.2	111	14	0.98	886[11]	2012
Dartmouth	17.2	113	28	14	19.9	7	2	0.26	129	2012
Michigan	14.4	422	148	128	45.0	108	9	1.06	1279[2]	2013
Utah	14.2	222	118	88	53.3	89	17	0.75	410	2013
Harvard	13.8	368	204	65	22.7	78	10	0.93	650[27]	2012
Cornell	11.0	331	147	73	30.5	162	8	1.03	7822[6]	2013
UC Berkeley	7.9	142	70	61	57.5	37	10	0.43	708[22]	2012
Wash. Uni.	7.0	151	27	24	27.0	44	4	0.36	725[19]	2013
Pittsburgh	6.5	254	119	51	27.3	155	9	0.87	899[10]	2013
Illinois-Urbana	4.9	181	191	72	38.7	46	6	0.60	926	2013
Purdue	4.9	356	173	54	20.4	77	5	0.81	600	2012
Penn State	3.1	132	99	39	33.8	22	5	0.35	795[15]	2012
Georgia Tech	2.4	408	159	79	27.9	130	13	1.02	655[26]	2012
Ohio State	2.1	384	234	62	20.1	38	10	0.81	832[14]	2013
Arizona State	1.9	239	105	26	15.1	80	9	0.60	355	2012
Mean	36.8	305	157	73	31.4	72	9	0.94	822	-
Stand. Dev.	44.7	134	82	46	11.7	45	4	0.45	356	-

*Superscribed number represents the rank of the university R&D expenditures in FY 2011 reported by US NSF [32].

3.2. Metric data collection

For those universities studied from the NSF 30 list, research expenditure data were obtained directly from the NSF FY2011 report [32], and their associated ranks are the superscripted numbers on the expenditure data listed in Table 1. Otherwise, expenditure data are obtained from either the TTO's websites or the FY2011 AUTM Report [13]. Note that the effect of research expenditure having 1-2 years of time lag on TTO activities is normal. As indicated in Table 1, on average, each of these 30 universities spent $822 million in sponsored research, with research expenditure of each university varying from $129 million for Dartmouth College to $2.25 billion for Johns Hopkins University. Nonetheless, the thirty universities studied are all RU/VH (very-high research activity) universities categorized by the Carnegie Foundation for the Advancement of Teaching in 2010 [33], given that it is used extensively as the de facto standard by higher education researchers.

The performance metrics listed in Table 1 include TTO revenue, number of innovation disclosures, number of US new patent applications, number of US new patents issued, number of licenses signed, number of startup companies launched, and R&D expenditures. Because not all of the studied universities reported their FY2013 data by the time this article was written, 20 of the thirty data sets reported in Table 1 are from FY 2012. All values are obtained either from the TTOs' websites or from direct communication with the TTOs. In fact, all 2012 data have been compared and verified with the data reported by the AUTM FY2012 Licensing Activity Survey [14]. The number of invention disclosures reported in the table does not include copyright and material (including chemicals, plant- or animal-derived material, and software) disclosures. The number of US patent applications does not include US provisional and international applications, while the number of US patents issued does not count international patents. The number of commercial licenses may not count copyright and material transfer agreements. The number of startup companies launched counts all types of commercial organizations.

3.3. Correlations of patents issued to research expenditures

As mentioned earlier, the major incentive of the Act is derived from federal government-funded research projects and research expenditure is the original source or driving force for university technology transfer. In this subsection, the relationships between research expenditure and TTO performance matrices are evaluated by using linear regression or data correlation. Note that, in FY 2011, all US universities spent $65.1 billion in sponsored research, 63% of which was sponsored by federal agencies [32]. For leading research universities, the portion of research funding from the federal government is even higher.

Correlation analyses between research expenditures and two metrics, the numbers of patents issued and licenses agreed, are performed and the results are shown in Fig. 3. As shown, the data points are randomly distributed in the figure and no appropriate functions can be found to fit the data to be correlated. The corresponding coefficient of determinations (R^2) is 0.06, which implies that there is a >93% likelihood that annual numbers of patents issued are not correlated well with annual research expenditures. In the correlation analysis, the R^2 coefficient specifically gauges the fitness of the correlation. The R^2 coefficient is an overall measure of the deviation of a correlation regression to quantify how well the correlation curve (or function) represents the data. The coefficient always lies between 0 and 1. A value of zero occurs when two variables are completely independent of each other, while it reaches 1 when two variables correlate perfectly, i.e., no deviation from the correlated curve [34]. Nonetheless, the slope of the linear correlated line shown in Fig. 3 is 0.033 patents/$1 million, which represents growth rate of the number of patents for every million dollar increase in research expenditure.

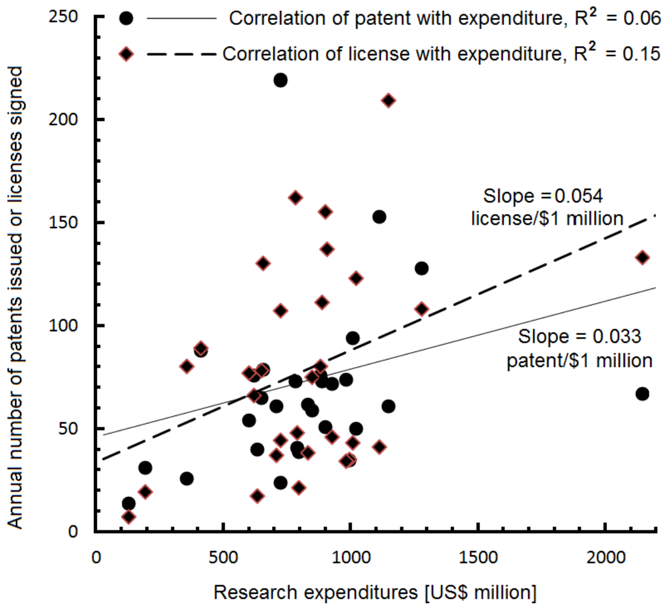

Fig. 3 Correlations of research expenditures to annual numbers of patents and licenses for 30 major US research universities

The present findings are somewhat consistent with the finding, recently reported by Tseng & Raudensky [7], in which total university patents are not correlated well with total university research expenditures, especially from FY 2000 to FY2010. However, researchers [27], [35] have reported that annual numbers of university invention disclosures are increasing as a function of growing research expenditures. They argued that increases in R&D funding could enhance faculty research capability by supporting graduate assistants and technicians and by providing needed equipment and supplies. Research dollars can also be used to compensate faculty during summer months, so they can focus on research instead of teaching summer classes. It is expected that the numbers of university patents issued should be proportional to the numbers of invention disclosures. The reasons for differing behaviors of disclosures submitted and patents issued are not clear. Further research on correlations between patents issued and research expenditures should be encouraged.

3.4. *Correlations of research expenditures to other TTO performance metrics*

Fig. 3 also shows the correlation results between research expenditures and license agreements. If a linear regression is applied, R^2 is 0.15, which is better than that of the patent correlation, but still too low to have a reliable correlation. The current finding is also consistent with the results obtained by Tseng & Raudensky [7], in which total university licenses assigned are not correlated well with total university research expenditures, especially from FY 2000 to FY2010. Again some researchers [27] indicated that the annual numbers of licenses agreements and annual research expenditures can be correlated well. Thursby et al. [21] also suggested that increased numbers of university disclosures or licenses are more dependent on the willingness of faculty to engage in commercial activity than a change in research profile. The slope or growth rate for the correlation is 0.054 licenses signed per $1 million.

Similarly, the correlations of research expenditures to annual numbers of innovation disclosures and of patent applications filed are shown in Fig. 4. The coefficient R^2 is 0.20 for the innovation disclosure correlation and is 0.04 for the patent application correlation. Although $R^2 = 0.20$ is still not high enough to make the correlation reliable, it is much higher than that of the patent correlation shown in Fig. 3. This is consistent with the suggestion made by Xu et al. [27], who find that university invention disclosures increase with the R&D expenditures.

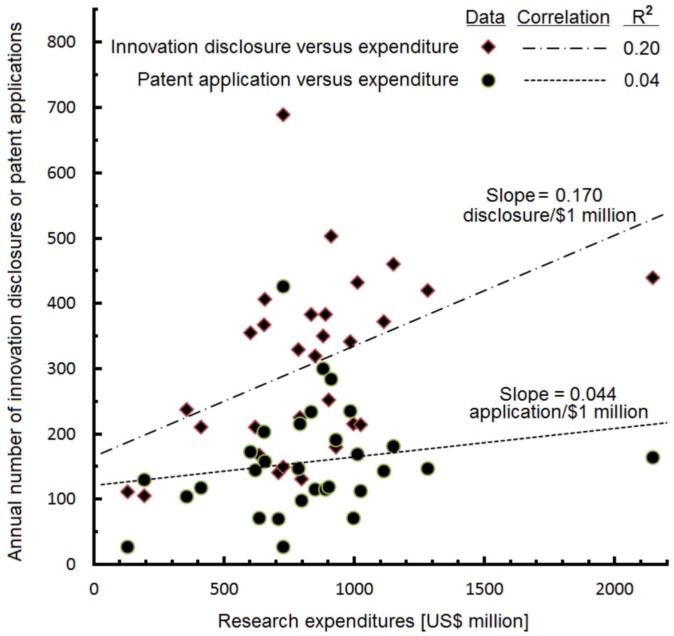

Fig. 4 Correlations of research expenditures to annual numbers of innovation disclosures and patent applications for 30 major US research universities

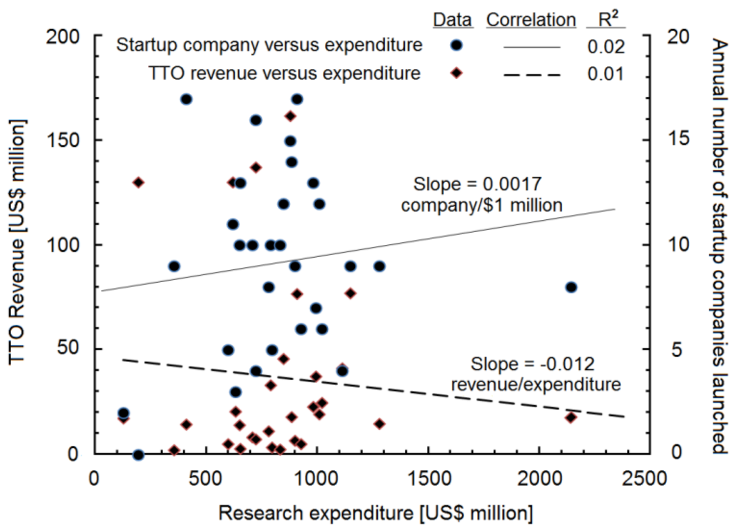

Fig. 5 Correlations of research expenditures to annual numbers of startup companies and TTO revenue for 30 major US research universities

The correlation of research expenditures to annual numbers of startup companies launched is performed and the results are shown in Fig. 5. The fitness of the correlation, or R^2, is quite low at 0.02 and the slope is 0.0017 startup companies per $1 million dollars. The present finding that startup companies created are not correlated well with annual research expenditures is also consistent with those reported by Tseng & Raudensky [7], who studied the history of university startups launched from 1993 to 2012. They suggested that one of the reasons for such a low R^2 may be that the numbers of startups launched by universities are generally small and are one-order of magnitude less than that of patents granted or licenses signed.

The results of the correlation between TTO revenue and research expenditures are also depicted in Fig. 5. It is interesting to point out that the slope of the correlation between TTO revenue and research expenditure is negative, indicating that, by increasing $1 million research spending, TTO income decreases by $11,900 dollars. This finding is quite amazing! However, the associated R2 is less than 0.01, which implies this finding is totally unreliable. One of the reasons for this unreliable finding may be the “big-hit” phenomenon. In a small number of major universities, TTO revenues are highly concentrated on a few licenses or patents [15]. According to Krieger [36], the 10 campuses in the University of California system, which includes four universities: UC-Berkeley, UCLA, UC-San Diego, and UC-San Francisco considered in Table 1, earned a total of $103.1 million in licensing revenue in 2010, of which about half are derived from five patents. Similarly, about two-thirds of Stanford's TTO revenues come from just three patents among its 9,400 inventions [37].

The correlation results reported in the present section are summarized in Table 2. As shown, research expenditure cannot be correlated well with all the metrics considered. If there is any influence of research expenditure on the metrics, it should be relatively minor and irregular. The irregularity can be due to the nature of the research funding source. For instance, if research funding is provided by a defense-related agency or program, the research results or technology developed can be considered to be confidential or classified. Frequently, technology transfer for commercialization is not encouraged or is even prohibited by the agencies or program. Nevertheless, the correlation results provide the foundation that the six metrics selected are mainly influenced by effort and achievement of TTOs and not by research expenditures, which is the responsibility of offices other than the TTO. Consequently, an overall performance metric (OPM) for the TTO can be reliably formed by these six metrics. The development of the OPM is the major subject presented in the next section.

Table 2 Correlation results with weighting factors

Metric correlated with R&D expenditure	R^2	Slope [No./$M]	Weighting factor	
			OP metric	PC ratio
Patent No.	0.06	0.033	0.0010	1.0
License No.	0.15	0.054	0.0025	0.0
Disclosure No.	0.20	0.170	0.0010	0.5
Patent appl. No.	0.04	0.044	0.0010	0.5
Startup co. No.	0.02	0.0017	0.0025	0.0
TTO revenue	0.01	-0.012*	0.0050	0.0

* Dimensionless

4. Overall Performance Metric and Patenting Control Ratio

Many stakeholders such as academic researchers, technology transfer offices (TTOs) and private industry are involved in technology transfer have called for a comprehensive way to measure the effectiveness or performance of TTOs [31]. In this section, the performance is evaluated and analyzed for each of the 30 major research universities by a newly developed metric, called the overall performance metric (OPM). This OPM is based on the six leading metrics selected in the precedent section. The rationale and procedures in developing this overall metric are presented and scores for each of the 30 selected universities are compared and discussed. A supplementary parameter, called the patenting control ratio (PCR), is also implemented for gauging the effectiveness of the patenting policy and procedure adopted by the universities studied.

4.1. *Overall metric for TTO performances*

In the preceding section, it has been demonstrated that research expenditure cannot be correlated well with the six performance metrics; thus, research expenditure has very limited influence or impact on the six metrics. As a result, the six metrics should be mainly related to the performance of TTOs in different degrees of influence on the relevance to the metric considered. The weighting factor for each of the six metrics is estimated to represent its influence or relevance to the TTO's overall efforts. The higher the relevance or influence of the metric to the TTO efforts, the higher the weighting factor is. Consequently, the OPM can be formulated as:

$$\text{OPM} = \$\text{M revenue}/200 + \text{no. of licenses}/400 + \text{no. of startups}/400 + \text{no. of patents}/1000 + \text{no. of disclosures}/1000 + \text{no. of patent applications}/1000 \quad (1)$$

where OPM is a combination of the TTO revenue and the numbers of licenses agreed, startups launched, patents issued, disclosures submitted, and patent applications filed, associated with different weighting factors, which are also adjusted to make the average OPM value close to 1. The OPM is developed based on "outcomes" instead of "process". The TTO revenue is the most important outcome of the entirety of TTO activities, while the other five metrics are outcomes of the five major steps (or activities) of the technology transfer process illustrated in Fig. 2.

The level of importance of each of these six metrics is represented by a weighting factor to achieve fairness and reliability of the contribution of each metric considered. The TTO revenue is a major source for covering TTO spending and is often used as the benchmark for gauging a TTO's achievement. The weighting factor for revenue is 0.005 for every million dollars received. License income is the major revenue source for TTOs and is also one of the most important activities which are primarily initiated, performed and executed by TTO's staff; a weighting factor of 0.0025 is assigned for each license assigned, which is one-half of that for TTO revenue.

The weighting factor for each startup company launched is 0.0025 because the amount of effort of a TTO spends on a startup is normally similar to that of licensing. The equal weight value assigned for startups can provide some incentive for a TTO because many government programs, including the Act, encourage technology transfer activities directly towards a small-business or startup. One may argue that the value assigned to the startup weighting factor is too high if one believes that a primary reason large numbers of startups are launched, especially in an economic recession with a high unemployment rate, is because starting up a company is an easy option for graduating students to hide their unemployment. Also, during economic recession, industry is less interested in licensing activities [7].

Finally, patenting activities measured by the numbers of innovation disclosures, patent applications, and patents granted are the main source to provide intellectual property to be transferred and should have an equal weight as that for licensing. TTOs are mainly contributing to the management aspects of these activities, and researchers play the major role in these activities. Thus, each of the three activities is separately assigned a weighting factor of 0.001 for each of the activities performed. The combined weighting value for patenting is 0.003, slightly higher than the single value of licensing.

The information on TTO activities presented in Section 2.0 provides the basis for estimating these weighting factors, which are also summarized in Table 2.

4.2. Overall performance metric (OPM) evaluation for major research universities

The OPM for the thirty major research universities are calculated and their values varying from 0.26 to 2.33 are summarized in Table 2, where the mean and the standard deviation are 0.94 and 0.45, respectively. Among the 30 universities, MIT, Columbia, Stanford, and Univ. of Washington are excellent performers with scores higher than 1.60, while the scores of Dartmouth, Penn State, and Washington Univ. are less desirable with values less than 0.40. Eight of the 30 universities with OPM values between 0.95 and 1.60 should be considered as very good performers. The other 15 universities can be ranked as a good performer or at least having great potential to become a good performer.

Universities with less desirable scores may imply that their TTOs need to change their strategies or approaches for technology transfer. One has to be careful in using this metric because no expenditure or budget information or university size information is incorporated with these metrics evaluated. It could be expected that if more resources are invested into the TTO, their scores could be higher. As a result, the performance evaluation should be used to compare a university TTOs from the same type of universities or its peers. For instance, Dartmouth College is much smaller than the other 29 universities by comparing the sizes of the student body or faculty members. As a result, the low score obtained by Dartmouth is not fair because no size effects are considered in calculating the OPM. Also, it would be better to compare the OPM scores with the amount of TTO expenditure to eliminate unfair effects on some smaller TTOs.

One should be careful in comparing the present results with other studies as well, since the metrics used may be defined differently from those used by other studies. For instance, for licensing revenue, some universities include income based on royalties, upfront licensing fees, and software licenses, while other institutions report equity sales and distributions, maintenance fees, and/or legal settlements. With patents issued, many universities only count patents granted in the U.S., while others include patents approved from either the U.S. or abroad. The timeliness of reporting may also be a problem, because many universities do not update their performance data every year. The lack of uniform reporting standards and metric definitions can make the comparison less reliable or meaningful and can cause unnecessary confusion to determine what strategies work best for a TTO.

In the present study, the collection of metrics data is mainly based on self-reporting or website searching (including AUTM data), although the authors try to be consistent in the data collection, especially through electronic communication. Furthermore, the OPM is focused on the outcome instead of the process of technology transfer, so some decent efforts by TTO may be ignored in the calculation or may not be fully reflected in the metric values adopted. The activities emphasized can be different from university to university. For instance, the performance of a TTO can be highly affected by the strategic objective set by the university and pursuing high scores to some of the metrics considered in Eq. (1) may not be the mission of the university. As a result, a university that has a more TTO-friendly strategy could be expected to have a higher OPM score. Also, faculty members often argue that the primary mission of a university should not be emphasized on the commercialization of the technologies developed from their research finding.

4.3. Patenting control ratio (PCR) and comparison

The PCR is a combined parameter of three metrics, i.e., the number of invention disclosures, the number of patent applications, and the number of patents granted. It can be expressed as:

$$PCR = 100 \text{ x no. of patents issued/ (no. of disclosures/2+ no. of patent applications/2)} \quad (2)$$

where PCR is in [%] and is a measure of the effectiveness of the patenting process adopted by a TTO, where the number of invention disclosures and the number of patent applications are used to normalize the number of patents issued because these two numbers are the measure of how much work or effort is done within the university for patenting.

The PCRs for thirteen major research universities are calculated and their values with the mean and associated standard deviation are summarized in Table 1. As indicated in the table, the mean of the PCR% is 31.4% with a standard deviation of 11.7%, which may imply that the norm of this ratio should be between 26% and 36%. If the ratio is higher than 31%, it may indicate either the quality of the disclosure is generally good or the patenting procedure is well managed by the TTO. However, this ratio should not be too high, because, it means the internal reviewing process is to too stringent or too tough, which may cause some good inventions to be mistakenly screened out or rejected; this could also decrease the enthusiasm of the faculty to cooperate with the TTO.

This ratio can be used to gauge the effectiveness of the patent budget being spent or the properness of the patenting budget. As indicated in Table 1, the PCR varies from 15.1% to 59.2%. Wisconsin, UC Berkeley, Michigan, and Stanford have scores higher than 50%, while Arizona State, Colorado, Uni. of Washington, and Dartmouth have values less than 20%. The former four should request an increase in their patenting budget next year, while the latter four should work harder to avoid their patenting budget from being cut. The higher the ratio value, the higher the patenting budget should be appropriated in the future.

Certainly, an adequate range of this ratio can be adjusted by each university based on internal benchmarking data and the goals or strategy set for its TTO. It is also understood that patents granted may be the outcome of patent applications filed one or two years before. However, a reasonable number of benchmark universities is selected, and each university studied in the table is relatively large. Therefore, the number of disclosures or patent applications should be quite stable and the variation from year to year should be relatively small as a whole. Certainly, more studies to obtain more data sets and to perform analysis on this ratio should be encouraged.

To further illustrate the appropriateness of these two parameters or variables (OPM and PCR) proposed, Fig. 6 shows the correlation of the OPM with the PCR with $R^2 = 0.01$. Since R^2 is extremely small, this implies that these two variables, OPM and PCR, are almost totally independent of each other, which means that these two variables can independently measure the behaviors proposed. Also, because the data points are nearly normally distributed in most of all the directions in this two-variable space, it suggests mathematically that these two variables are naturally suitable for the respective quantities proposed. Certainly, a more rigorous analysis is needed to reach the conclusion or statement made above.

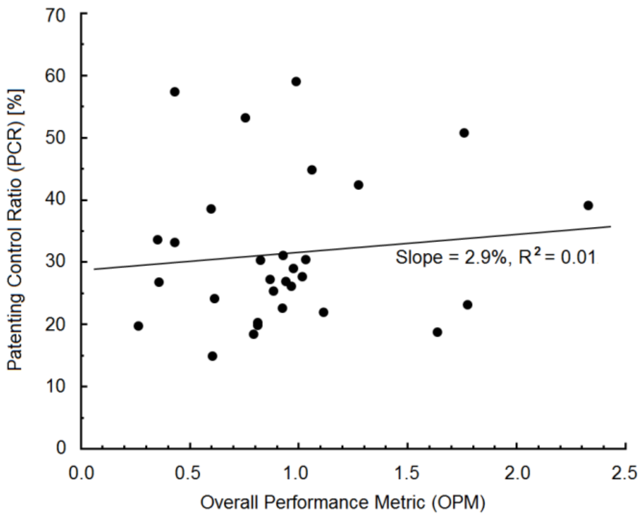

Fig. 6 Correlation of overall performance metric (OPM) with patenting control ratio (PRC)

5. Concluding Remarks

Ever-increasing competitive and financial pressure have spurred universities to pursue technology transfer of their intellectual property, more specifically their patents, to secure additional revenue for universities as well as to promote institutional prestige to attract better students and faculty. However, there is a lack of a simple, yet meaningful way to measure the effectiveness of technology transfer activities performed by technology transfer offices (TTOs). In this article, the current status of technology transfer activities is first reviewed to provide the foundation for the selection of six leading metrics for assessing the performance of university TTOs. These selected metrics are then used for developing two normalized metrics, overall performance metric (OPM) and patenting control ratio (PCR), for measuring the TTO performance and patenting efficiency, respectively. These normalized metrics enable a university to standardize its performance evaluation process and to establish benchmarks for strategic decision, which help to allocate appropriate resources to TTO and to yield the highest technology transfer performance.

Following a review of the major activities performed by TTOs, correlation analyses are conducted to illustrate that the effects of research expenditures on these 6 performance metrics are minimal and indeed that these metrics are relevant and effective to the measurement of TTO performance. Based on these six metrics, an overall performance metric (OPM) is developed and used to evaluate the effectiveness of the TTO for each of 30 major research universities. The OPM scores for the 30 universities are also compared with each other and provide a benchmark for TTO performance evaluations. The score can be specifically used by a university to evaluate its TTO performance (or service) and whether alternative approaches, such as resource allocation, personnel configuration, disclosure procedure, or university policy used by other peer universities would produce better scores. Certainly, the OPM can be more objective and reliable, if it can be normalized by the TTO's expenditures or other resources, such as TTO size. Moreover, the weighting factors used to form the OPM should be studied further to increase the objectivity and reliability of the OPM.

The patenting control ratio (PCR) has also been developed and used to gauge the appropriateness of the patenting process set by each of the 30 universities considered. The mean and standard deviation of the PCR for the 30 universities are 31.4% and 11.7%. If a university's PCR is much higher than this mean value, this implies that the patent screening (or reviewing) process may be too tough, which can damage the enthusiasm of the faculty's willingness to make invention disclosures or to cooperate with TTO. However, if this ratio is too low, it may indicate that the TTO is over-budgeted and the patenting screening process should be more stringent.

As a final concluding remark, in this country, products based on university innovations enter our marketplace each day, and a large number of new companies supported by university-industry ventures are launched each year. All of these technology transfer activities put Americans to work and thus bolster our economy, which benefits all of us.

Acknowledgments

This paper is based on the lecture delivered at NETME Forum sponsored by NETME center, Brno University of Technology (BUT), on October 2, 2013. The authors are grateful to Czech Ministry of Education, Youth and Sports to provide the government endowed professorship to the first author at BUT to prepare this paper under Project No. HEATEAM-CZ.1.07/2.3.00/20.0188. The authors should acknowledge the following Technology Transfer Offices for proving their performance data and useful suggestions: Dr. Alan Paau of Cornell University (11/03/2013), Dr. Ragan Robertson of University of California at Los Angeles (11/03/2013-11/09/2013), Dr. Alexander P. Ducruet of University of Pittsburgh (11/03/2013-11/09/2013), Dr. Katharine Ku of Stanford University (11/12/2013), Dr. Sara Burmeister of University of Washington (11/12/2013), Dr. Brad Castanho of Washington University (11/12/2013), Dr. Robin L. Rasor of University of Michigan (11/12/2013-11/013/2013), Dr. Emily Bauer of University of Wisconsin (11/12/2013-11/013/2013), Dr. John F. Ritter, Princeton University (11/12/2013-11/014/2013), Dr. Monique J. Timberlake-Brady of University of Pennsylvania (11/13/2013-11/014/2013), Dr. Jessica Mandl of Arizona State University (11/01/2013-11/015/2013), Dr. Cassi Betker of University Minnesota (11/13/2013-11/015/2013), and Dr. Rochelle Jones of Northwestern University (11/13/2013). The hospitality and the facilities provided by Arizona State University during the writing of this paper should also be acknowledged.

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