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University – Industry Relations: Evidence Based Insights

Prof. Arnon Bentur

Dr. Avigdor Zonnenshain

Rafi Nave

Ella Barzani

Ilia Zatcovetsky

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Abstract

The linear innovation model is no longer sufficient, since the interactions between basic research, applied research and development are much more complex, with the boundaries between them becoming blurred, as is the case with boundaries between engineering and scientific disciplines. This change is the driving force for re-evaluation of the role and mode of operation of universities, from one where the only two missions were education and research, to one where a "third mission" is added, labeled sometimes as "technology transfer", whereby the university should be actively and directly involved in getting its know-how into the industry and to the market, for the benefit of the economy and society. Within this context the term "entrepreneurial university" is frequently used.

In the case of technological universities, the third mission is accomplished by developing special modes of interactions, of direct transfer of technology to the industry, and this involves a range of mechanisms, all falling under the umbrella of "university-industry relations". The object of the present report is to explore these relations and discuss their effectiveness, and at the same time resolve, based on hard evidence (quantitative indices and case studies), to which extent they were successful in reaching their goals without compromising the core academic values of education and research.

National policies for IP protection of university know-how were established with the view that this is an effective mechanism by which universities will be encouraged to be pro-active in transferring their know-how to industry to facilitate national economical and societal benefits. The Bayh-Dole act of the 1980 in the US, which is considered as a corner stone of these policies, was enacted with this spirit.

Quantifying the success of such activities over the years is not simple as many of the influences on society are indirect in nature. However, some insight might be gained by considering the volume of such activities and their financial inputs and outputs. Most quantitative assessments are based on evaluation of patenting and startup activities of TTO's and TLO's, reflecting a notion that has been sometimes erroneously developed over the years, that the main goal is technology commercialization for the benefit of the university, rather than the more wider goal of technology transfer. The technology commercialization is essentially a linear process moving from invention disclosure through patenting to licensing or startup formation, whereas technology transfer, which is based on cooperation with industry, is more entrepreneurial in nature.

The commercialization income has increased over time quite impressively. Yet if values are presented in relative terms, compared to total research funding, the view derived is quite different: On the average commercialization income makes up only a small portion of the total research funding, less than 5% on the average, and this value has been approximately the same over the last 20 years. At the same time, the research supported by industry has not been increasing and even shows some trend for decline in relative terms, being on the average less than 10% relative to total research funding.

These trends imply that the policies implemented through TTO's and TLO's are perhaps not effective in reaching the overall goals set within the context of the third

mission: The emphasis on commercialization is not yielding overall impressive results, while at the same time involvement of industry is almost at a standstill, when considering the relative income from industry supported research.

Views of this kind, which are based on average values of indices, can be challenged, when considering the large disparity between universities. Yet, even those universities which are high on the list of commercialization income, show small values when compared to the total research income. More than that, it has been argued that success in commercialization is the result of blockbusters, and those are more likely to occur in universities with larger overall research budget.

This state-of-affairs suggests that there is a need for re-evaluating and re-visiting university policies with regard to the third mission, and new and additional indices for evaluation should be introduced, which should not be based solely on commercialization income.

Policies should be set to guide the activities of the TTO's and TTL's, which need to balance between technology commercialization, which is more linear in nature, with technology transfer through industry cooperation, which is more holistic, active and entrepreneurial in nature. Goals should be set, and IP protection policies should be adjusted. Greater emphasis on technology transfer and more intimate cooperation with industry may result in increase in research funding as well as improved level and significance of research. More than that, such policies are more likely to be met by support of the academic faculty, and they should be an inherent part of the development of entrepreneurial activities in universities, based on an ecosystem which includes education as well as research.

A comprehensive approach for all the stakeholders should be considered:

Academia

- Mechanisms: move emphasis from commercialization to transfer of technology
- Faculty: take into consideration the differences between faculty personal profiles with regards to their will and skills to follow up with entrepreneurial activities of their invention and develop flexible policies to account for these differences
- Finances: move from royalties income to industrial research funding
- TTO/TLO: entrepreneurial approach of nurturing and intimate industrial relations
- IP policies: relaxing, with view of long term industrial support and donations

Industry

- IP policies: flexibility for publishing in return for IP rights
- Nature of research: support explorative research, not just exploitive/applied research

Government

- Policies: develop policies with long term objective of having sustainable ecosystem
- Incentives: set criteria for incentives to universities for achieving third mission goals, based on multiple indices

The report is intended to serve also as a white paper for discussion of technology transfer and technology commercialization of universities in Israel and therefore it includes a chapter in which comparison is made between the performance of some Israeli universities with leading international ones, as well as interviews with leaders of the Israeli industry.

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1. Introduction

The most valuable contribution of the academia to society and economy is the human capital, engineers and scientists, educated at the universities, as well as the open knowledge produced through fundamental research. These are, perhaps, the most important roles of academia to the knowledge driven modern society of the 21st century, and are directly related to its core missions of education and research. The mechanisms by which this impact on society takes place are, to a large extent, tacit and indirect, and in many ways seem to be spontaneous, as is often implied in the linear model of innovation. In the case of economic impact through industrial innovation, it is quite obvious that a major vehicle of these influences is the human capital educated at universities, which is a key driver of industrial development and the carrier by which the know-how created in universities is transferred to industry and economy via the subtle and informal processes. This is one of the mechanisms which make up the process of "knowledge dissemination" which includes also mechanisms such as publishing and presentations and participations in conferences.

In the midst of the previous century, following the Second World War, this indirect and tacit process was considered to be sufficient for transferring knowledge to industry via an innovation process described by Vannevar Bush [Bush 1945] as a linear process, made up of the following stages:

Basic research → Applied research → Development → Production/Products

This linear innovation model is no longer adequate, since the interactions between basic research, applied research and development are much more complex, with the boundaries between them becoming blurred, as is the case with boundaries between engineering and scientific disciplines [Rosenberg 1994, Stokes 1997].

This change is the driving force for re-evaluation of the role and mode of operation of universities, from one where the only two missions were education and research, to one where a "third mission" is added, labeled sometimes as "technology transfer", whereby the university should be actively and directly involved in getting its know-how into the industry and to the market for the benefit of the economy and society. This should take place without relying only on the tacit and spontaneous influences associated with the core missions of education and research. The significance of this approach shows up in discussions which highlight the need of universities to be much more entrepreneurial, with the term "entrepreneurial university" being frequently used [Yoon and Lee 2013] [US Department of Commerce 2013] [Alvarez Garcia 2015] [Gibb 2012] [Ouchi 2011] [Eesley and Miller 2018] [EC-OECS 2012] [Graham 2014].

2. The "Third Mission" and the Entrepreneurial University

The implementation of the "third mission" is quite a challenge, as it requires new modes of actions to be taken, involving cultural change. All of these should be carried out with care, to make sure that they do not come at the expense of the contribution to society which is based on the first two core missions of education and research. In the case of technological universities, the third mission is accomplished by developing special modes of interaction, to provide direct transfer of technology to the industry. This involves a range of mechanisms, all falling under the umbrella of "university-industry relations". The object of the present report is to explore these relations and discuss their effectiveness, and at the same time resolve, based on hard evidence (quantitative indices and case studies), to which extent they are successful in reaching their goals without compromising the core academic values of education and research.

Several case studies have been reported to evaluate the success of universities which managed to promote their entrepreneurial nature, without compromising the two core missions. A notable example is MIT, where the success was the result of the development of an ecosystem with characteristics that can be resolved into 8 factors [O'shea et al 2007]:

Factor 1: Research funding

The ability to attract large sources of funding to support leading edge research.

Factor 2: Industrial funds for research

Source of funds is important; industry led research played a strong role in commercialization; such research improves education; industrial research could also be basic.

Factor 3: Quality of academic staff

The ability to generate cutting edge research to generate radical innovation conducive to commercialization.

Factor 4: Organizational characteristics

A number of organizational structures:

i. TLO - Technology Licensing Office

Proactive role, not waiting for pull, encourages disclosures, meets with VC's, promoting startups and taking equity in lieu of royalties.

A number of basic principles guide the conflict of interest policies for tech transfer – strict policies on managing it (Appendix A).

ii. Entrepreneurship development programs

Supplement education with formal and experiential education in entrepreneurship, drawing on the local alumni base and faculty role models. Such supporting activities are very important in MIT culture.

iii. Interdisciplinary research centers

At MIT and associated, but not within, such as Lincoln Lab, Whitehead Institute for Biomedical Research, Broad Institute, Media Lab.

Factor 5: University mission

MIT mission: "advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the 21st century".

Long term commitment to local economic development. Combining research university "linear model" with the land grant university "reverse linear model" of deriving research goals from societal needs. This provided entrepreneurial spirit. The thrust of the mission and policies is oriented towards would-be entrepreneurs.

Factor 6: MIT faculty culture

Tenure and promotion solely based on academic achievements and reputation. Outside activities are neutral factors.

The other aspect is that faculty are expected to support themselves and their research activities, with only little help from the University. Thus, MIT culture rewards "academic entrepreneurship". Therefore, carrying out research with a company or a new venture is not considered negative, provided that it enhances education and enables high quality research. Commitment to deep fundamental research, which is matched by the desire to transfer new knowledge and technologies into the world, is important and beneficial in many ways.

Taking time off to work in a company is not atypical although not favored or precluded. Nowadays such leave is even taken by non-tenured faculty.

Motivations driven by different reasons:

- Quest of faculty to validate their technology in the market-place.
- The game of business is interesting and stimulating to some of the faculty.
- Accumulation of wealth.

Factor 7: History and tradition

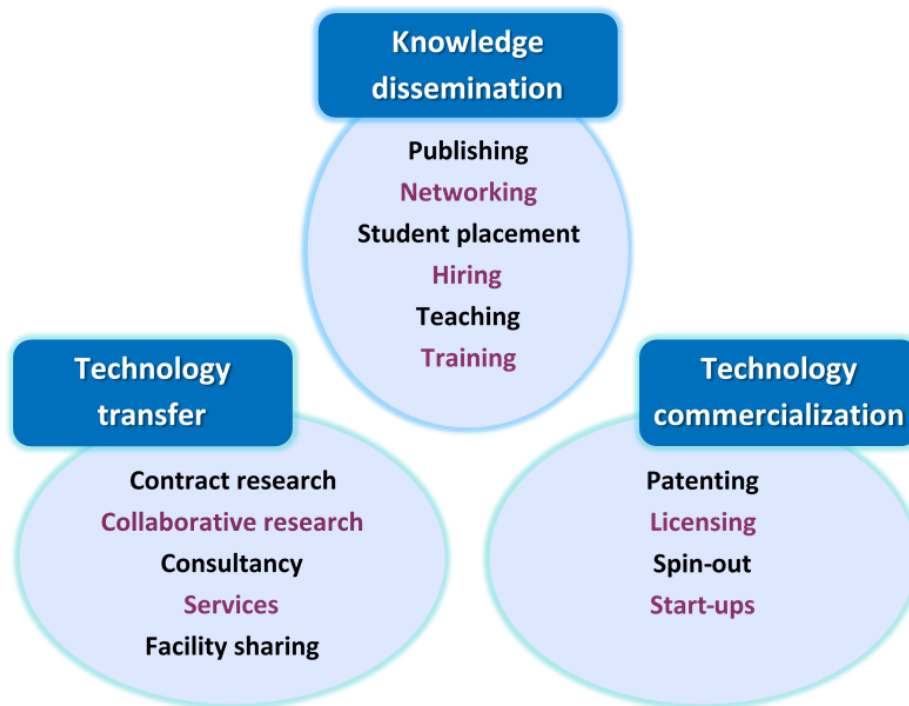
Tradition of industrial and military funding which led to commercially oriented innovations.

Factor 8: External geographical context in which it operates

Located in a leading high-tech cluster.

The active steps that a university must take in the transfer of know-how, which is an essential part of its expected third mission, requires a holistic approach, which includes several components, in addition to the basic knowledge dissemination, such as the ones presented in Figure 1.

Figure 1: Mechanisms of knowledge dissemination, technology transfer and commercialization



The items in Figure 1 have been proposed by [European Commission 2009] to quantify knowledge transfer from public research organizations in Europe. They are grouped here into three categories:

Knowledge dissemination: The traditional role of universities, such as open scientific publications, conference meetings, education of engineers and scientists. The know-how produced is, to a large extent, the result of fundamental research carried out in universities. The transfer to society and industry takes place by tacit diffusion processes.

Technology Transfer: Direct interactions between university researchers and industry through mechanisms such as contract research, joint research and consulting, government subsidies to generate generic technologies for interaction between a university partner and an industry partner, or consortium of several universities and industries. Facilitates establishment of interdisciplinary group of experts working together in a mode that stimulates synergy.

Technology Commercialization: Dominant mode of the Technology Transfer Offices (TTO) and Technology Licensing Offices (TLO) of universities, whereby faculty are required to disclose inventions and the TTO/TLO unit is in charge of commercializing it by modes such as patenting followed by licensing and creation a spin-off.

The terminology currently used in universities, "Technology Transfer", reflects essentially the efforts to commercialize universities' IP, and it is somewhat misleading, as it implies that this is the only mode of transfer. The transfer of know-how involves all three categories in Figure 1, whereas the pro-active technology transfer associated with the third mission of universities is based on both, "technology transfer" and "technology commercialization", as defined above. This terminology will be used throughout this report.

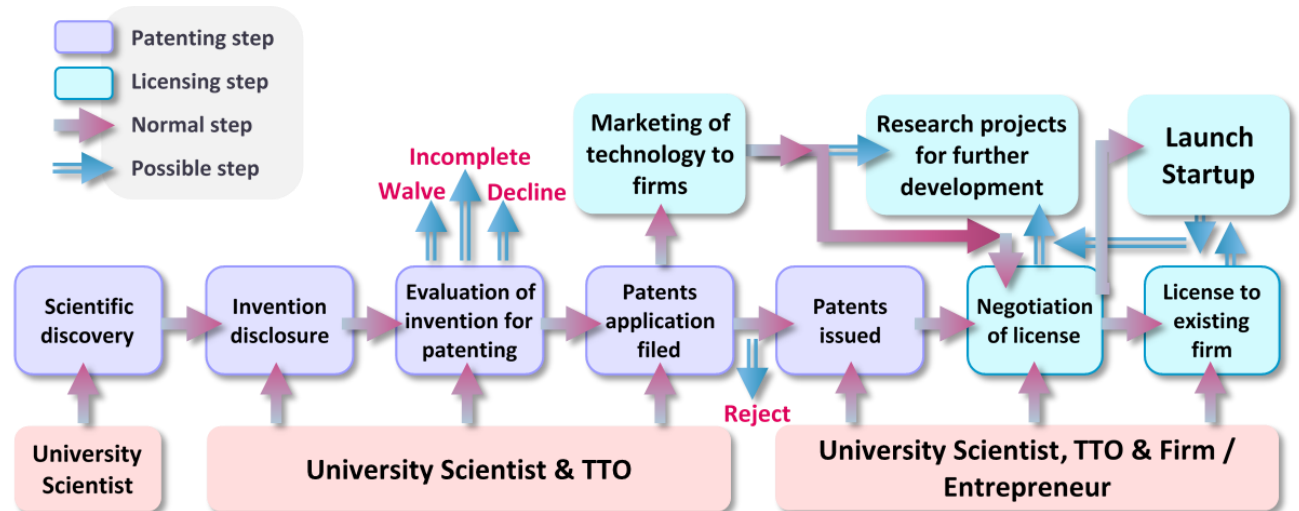
The Bayh-Dole Act of 1980 in the US was enacted based on the perception that university ownership of IP, produced by publicly funded research, will result in mobilizing universities to be pro-active in utilizing the fruits of research for the benefit of society, consistent with the idea of encouraging universities into being active in promoting the "third mission". Many of the developments, since then, at the universities, such as the establishment of TTO's and TTL's, as well as the increase in patenting activities, have been ascribed to this Act. An implied assumption in that step was that University ownership would enhance its activities and promote a cultural change that would result in technology transfer in its wider sense, to benefit society and economy et large.

In the present report various aspects of technology transfer and technology commercialization of universities will be quantified and critically analyzed in order to resolve the influences from the point of view of societal impacts and the policy implications. The report is intended to serve, also, as a white paper for discussion of technology transfer and technology commercialization of universities in Israel and therefore it includes a chapter in which comparison is made between the performance of some Israeli universities with leading international ones, as well as interviews with leaders of the Israeli industry.

3. Technology Commercialization

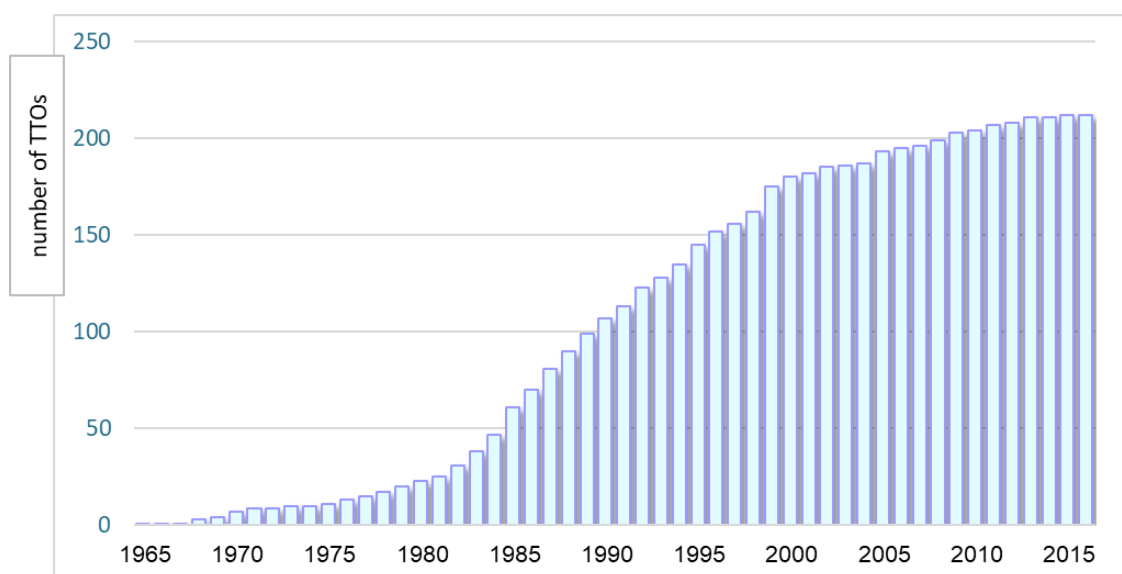
The mechanism of technology commercialization is presented in Figure 2, describing the different steps and the stakeholders involved in each.

Figure 2: Mechanism of technology commercialization by university TTO ¹

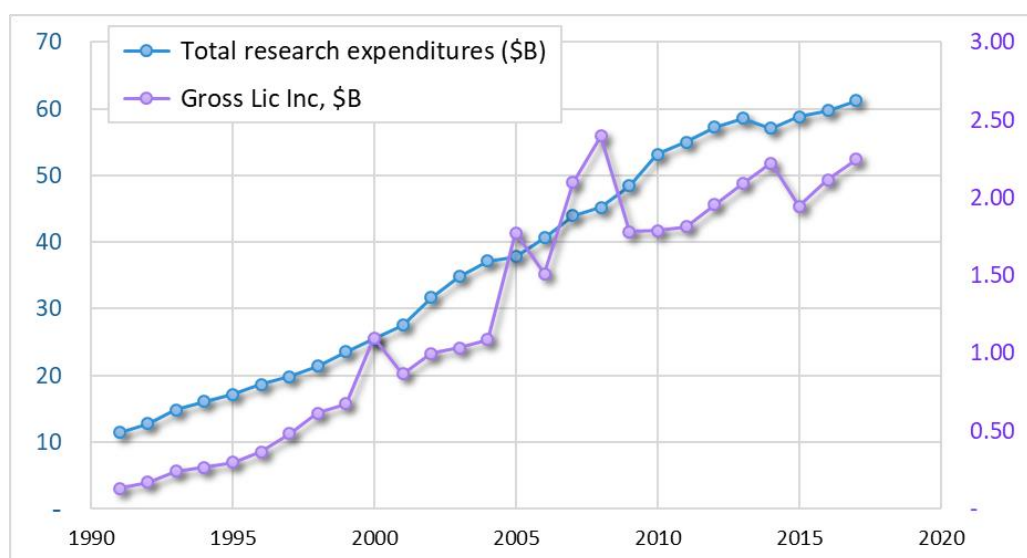


The evolution with time of the commercialization activity is presented in Figure 3 and expressed in terms of the number of TTO's/TLO's established in US universities over time. The rise in the number of TTO's/TLO's formed during the 1990's is related by some to be the result of the Bayh-Dole Act enacted in 1980, e.g. [Tseng and Raudensky 2014].

¹ After [Tseng and Raudensky 2014]

Figure 3: Development of TTO's in US universities, 1965-2015 ²

Over that time period there has been continuous increase in licensing activities and commercialization income, which accompanied increase in research funding, as seen in Figure 4 for US universities, based on AUTM data.

Figure 4: Increase in patents issued and license income in US universities over the period 1991-2017 ³

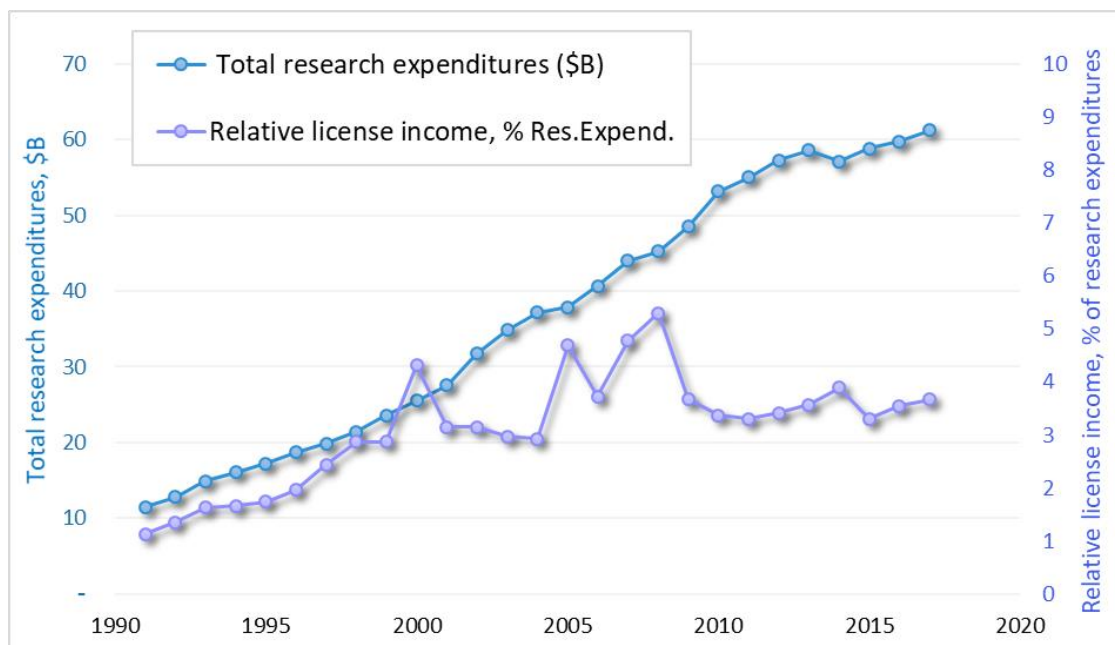
A more in-depth analysis suggests that the trends cannot be simply interpreted as rise in the intensity of commercialization activities and benefits, as highlighted in Figure 5,

² AUTM data, extension of data presented by [Valdivia 2011]

³ AUTM data

showing that the commercialization income remained practically constant relative to research funding over the last two decades.

Figure 5: Change over time of total research expenditures and gross licensing income (absolute and % of research expenditures) ⁴



In order to better understand these trends, there is a need to analyze the nature of the IP which is responsible for most of the commercialization income, as has been discussed in several reports, [Merrill and Mazza 2011] [Reslinski and Wu, 2018] [Love 2014].

Analysis of this kind indicates that most of the commercialization income is coming from a small fraction of the inventions, as seen in Figure 6 and Figure 7. Figure 6 presents the whole number of running royalties ("running royalties") and on the same scale the number of running royalties which provided income each larger than \$1M (">\$1M"). These are very small numbers compared to the total, and the chart includes the relative values for the ">\$1M", demonstrating how small is their number, less than 2.5%.

⁴ Based on AUTM survey; the number of universities surveyed increased from 72 to 115 during 1991 to 1993, thereafter increasing at a mild rate up to 160 in 2003, and from there on remained almost constant, to 163 in 2017

Figure 6: Running royalties and portion which yielded over \$1M income ⁵

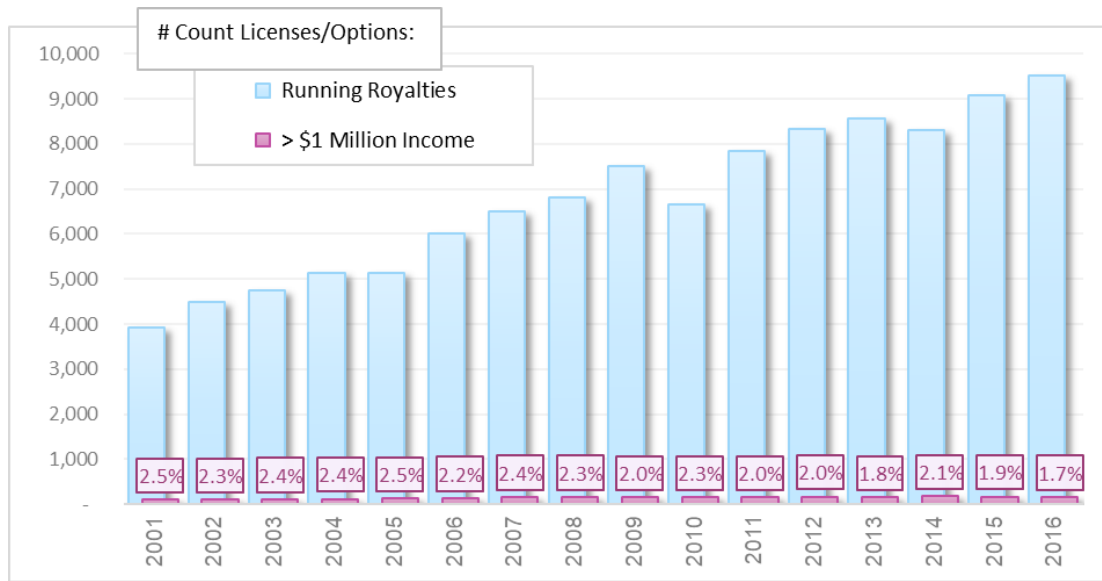
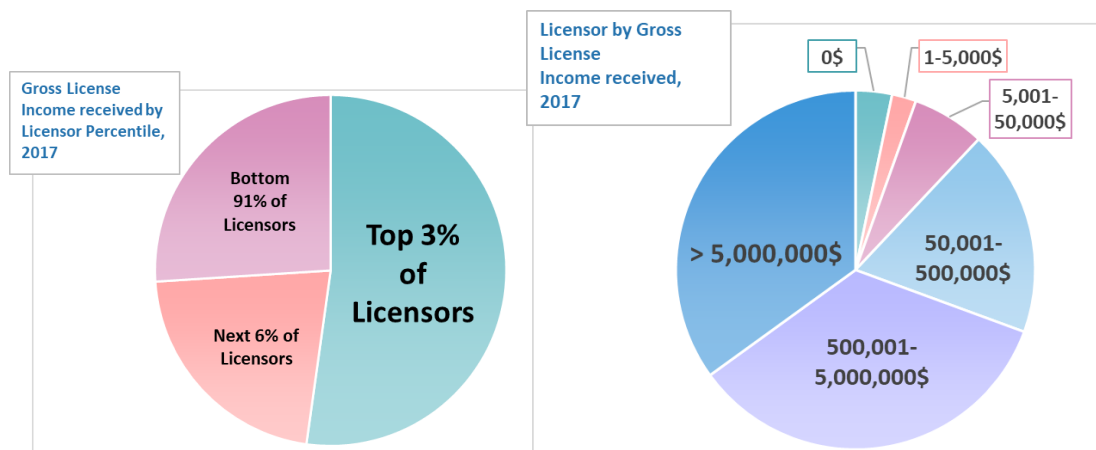


Figure 7: Distribution of commercial income in computer science and electrical engineering ⁶

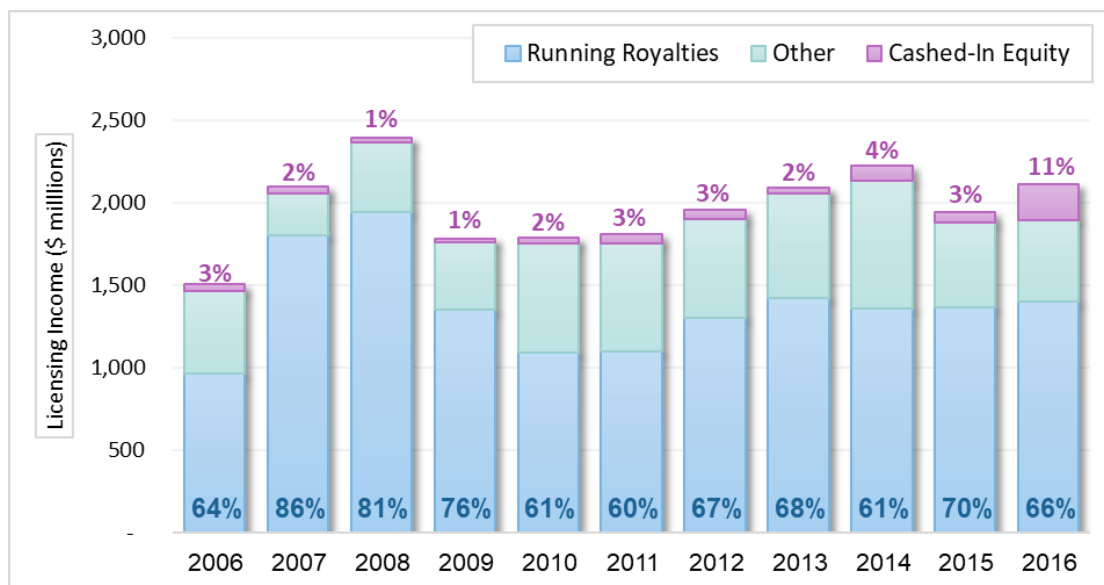


The commercialization income is largely obtained from running royalties and not cashed in equities, Figure 8.

⁵ AUTM data, extension of data of [Merrill and Mazza 2011]

⁶ [Love 2014], AUTM data updated to 2017

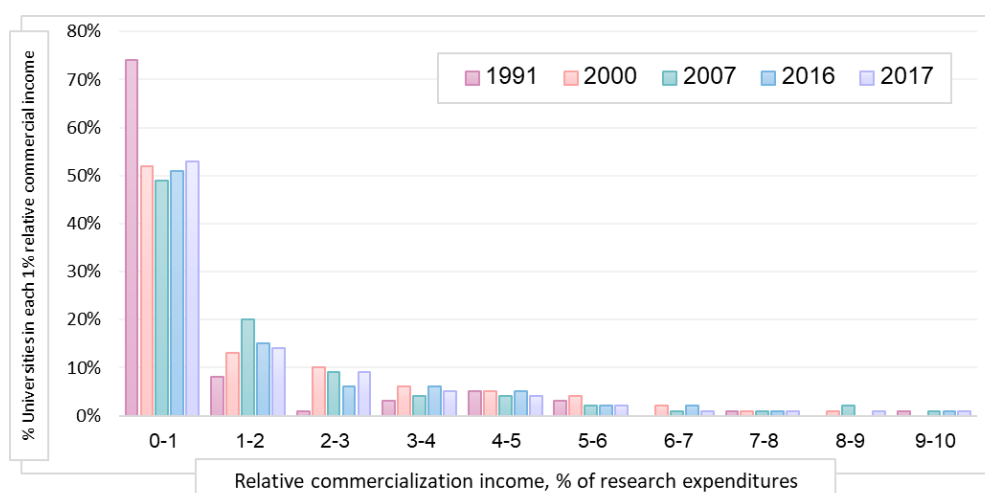
Figure 8: Gross licensing income broken down into the various resources: running royalties, cashed in equity and other, not characterized ⁷



The distribution of commercialization of income between universities during the period 1991 to 2017 is presented in Figure 9 and Figure 10, in relative terms, % of R&D expenditures.

The data indicates that most universities earn only a few percentages of income relative to their R&D expenditures, with 50% of the universities less than 1%, and about 85% less than 5%.

Figure 9: Distribution of commercialization of income in relative terms, % of R&D expenditures over the period 1991-2017 ⁸

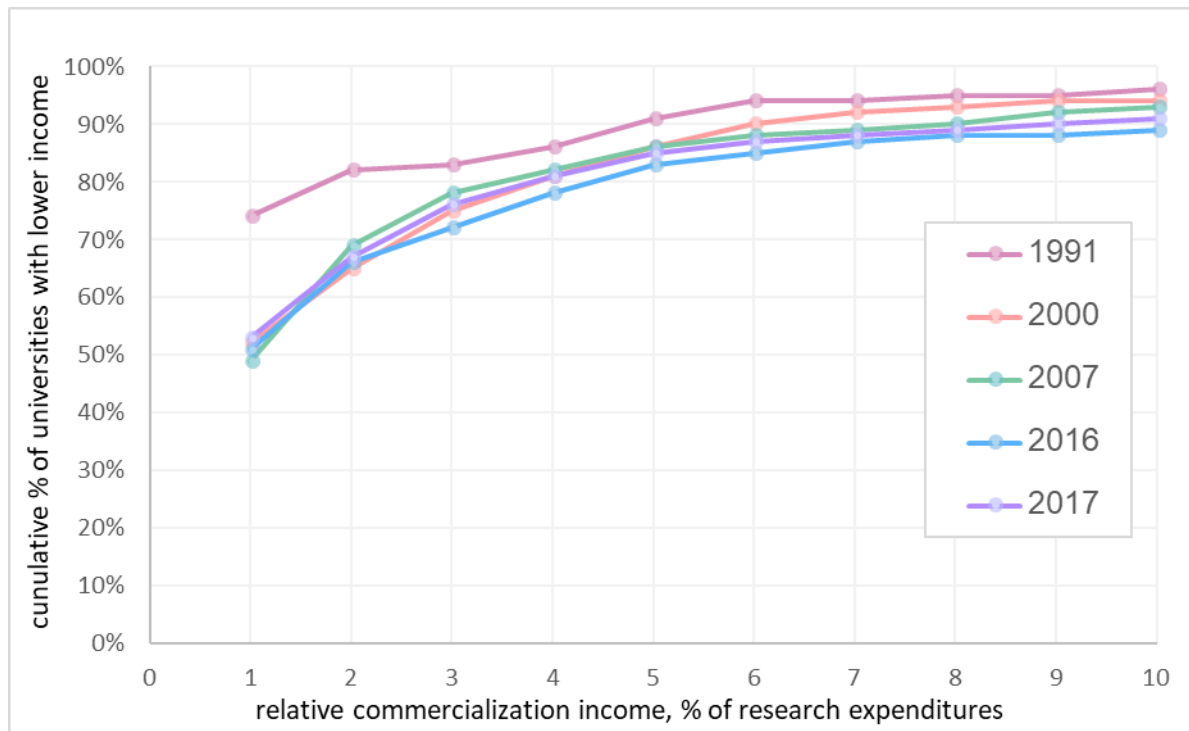


⁷ Using AUTM data of 2016, extending the data of [Reslinski and Wu, 2018]

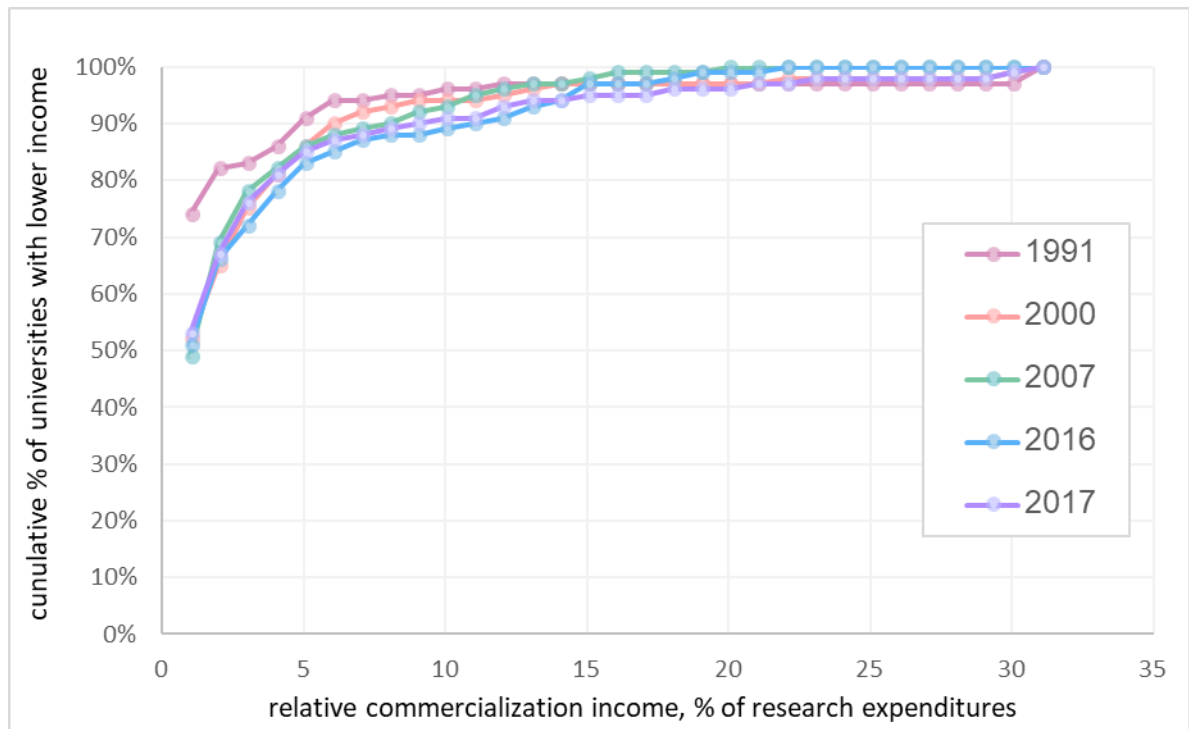
⁸ AUTM data

Figure 10: Cumulative distribution of commercialization income in relative terms, % of R&D expenditures over the period 1991-2017⁹

(a) Data up to 10% relative commercialization income



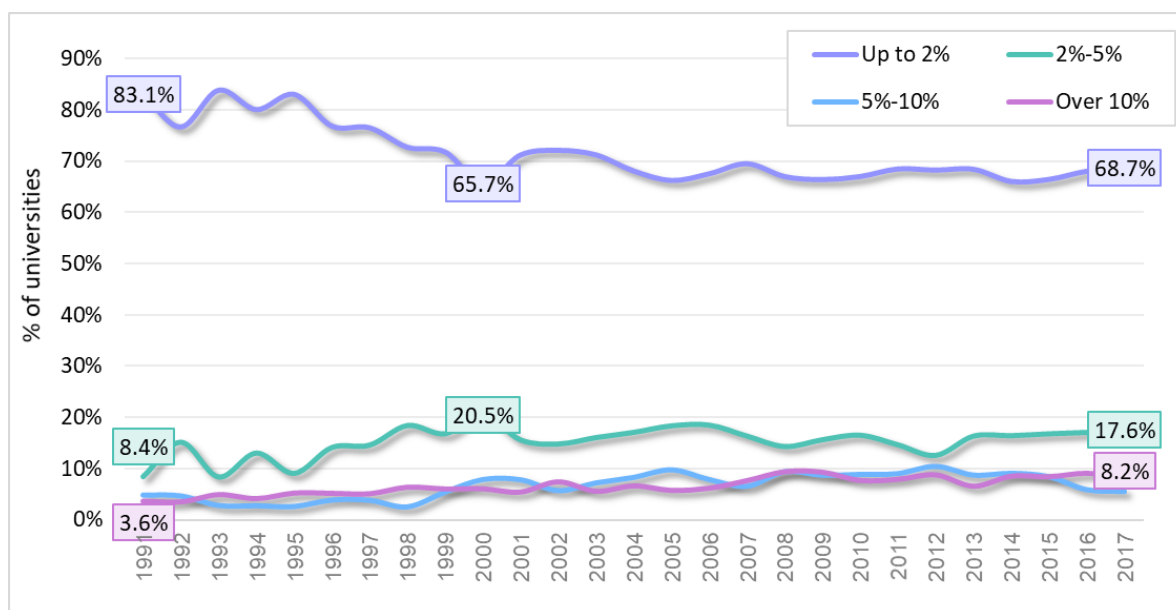
(b) Data up to 30% relative commercialization income



⁹ AUTM data

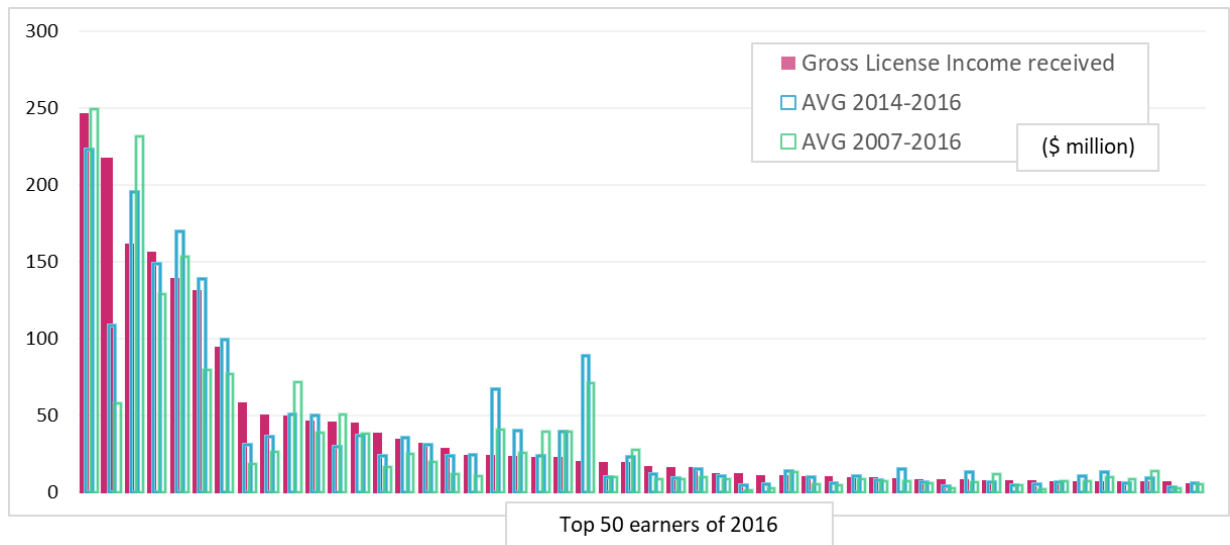
The distribution in income presented in Figure 9 and Figure 10 has not changed over the last period of almost 20 years, and this is further seen in Figure 11, based on AUTM data. It should be noted that the data up to about 2003 is based on increasing number of universities which were incorporated in the AUTM data base, but since 2003 it is about constant, footnote to Figure 5, footnote #4.

Figure 11: The relative number of universities within increments of relative commercial income (less than 2%, 2-5%, 5-10% and more than 10%) over the period of 1991-2017¹⁰

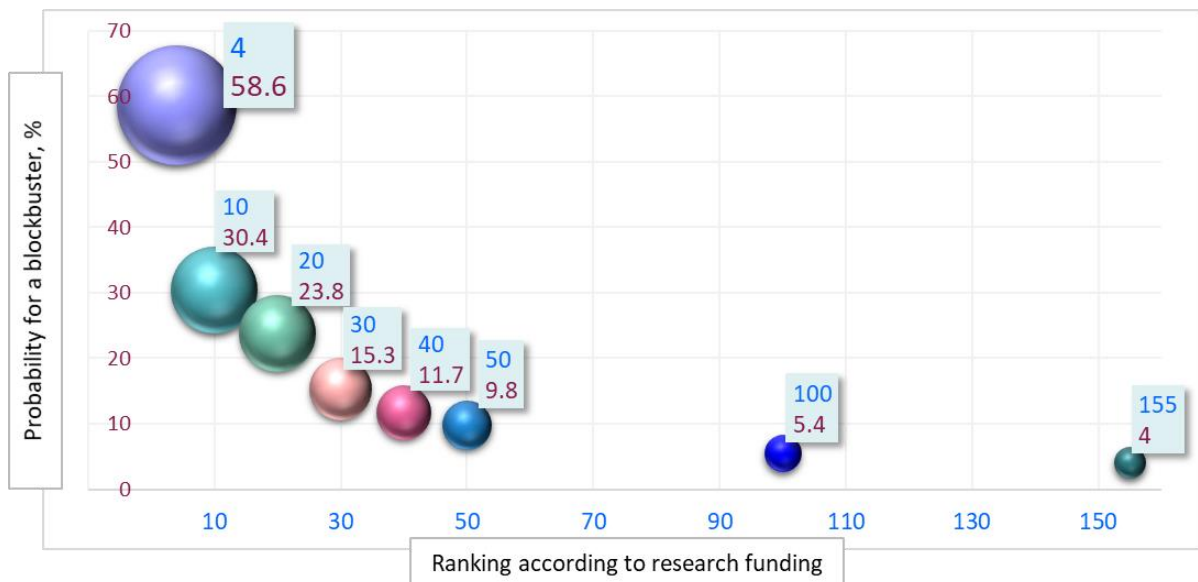


The distribution of commercial income of the top 50 earning universities shown in Figure 12 demonstrates, again, a skewed distribution, whereby a very small number of universities earn considerable income; the distribution curve falls sharply beyond the first 10 top earners, and beyond the 30 earner the income becomes low, below \$10M, which is only few percent of the universities budget.

¹⁰ AUTM data

Figure 12: Distribution of IP commercialization income of the top 50 university earners¹¹

The financial analysis of the data presented in Figure 5 to Figure 12 indicates that only a few of the inventions are commercialized, and only a few of the latter lead to income of some significance. In addition, only few universities earn significant income from IP commercialization. [Valdivia 2011] analyzed such trends and demonstrated that commercialization income is derived mainly from blockbusters, and the probability of such blockbusters is dependent on the overall research expenditures of the university. The results of model calculation as a function of research funds is presented in Figure 13.

Figure 13: Probability of a blockbuster patent as a function of research funds¹²

¹¹ Following analysis of [Valdivia 2013], AUTM data updated to 2016

¹² After [Valdivia 2013]

The income from commercialization tends to be skewed to a few blockbusters but it is also skewed towards life sciences, as shown in Figure 14 for data collected by Nature Biotechnology. The top 20 gross licensing revenue earners were selected over the 2009–2013 period and each university was contacted and asked for data related to just the life sciences. Similar trends were observed for most Israeli Universities, when considering the startups established by their TTO's/TLO's, Figure 15.

Figure 14: Life science portion of overall TTO output for top ten US universities, selected by Nature Biotechnology 2013¹³

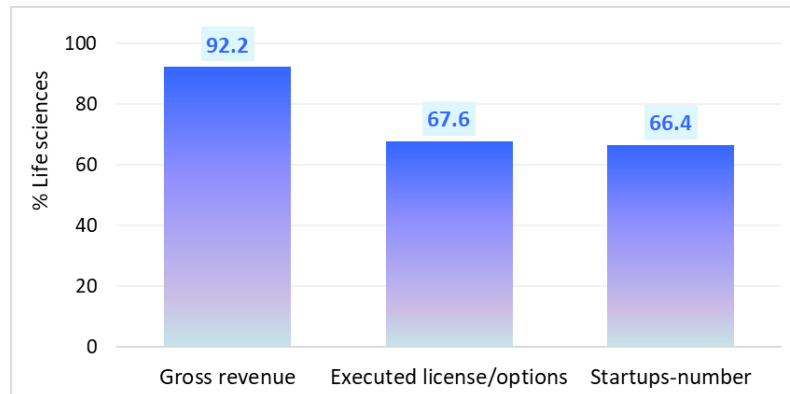
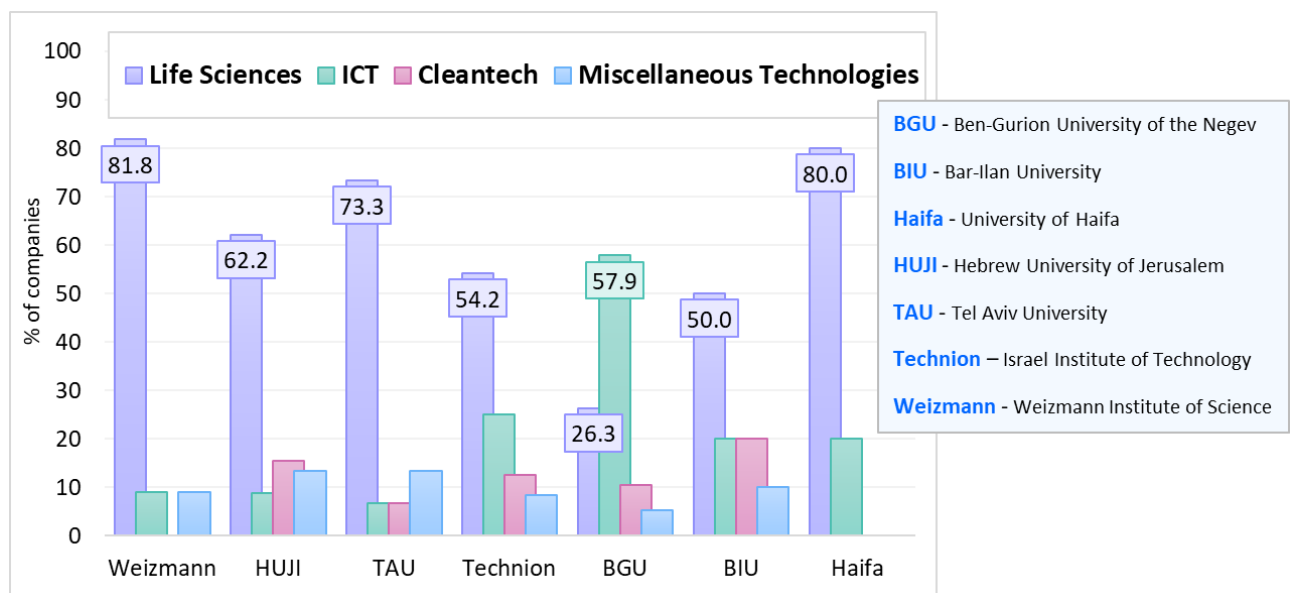


Figure 15: Distribution of the professional area of startups established by TTO's of Israeli universities over the period 2002-2017 ¹⁴



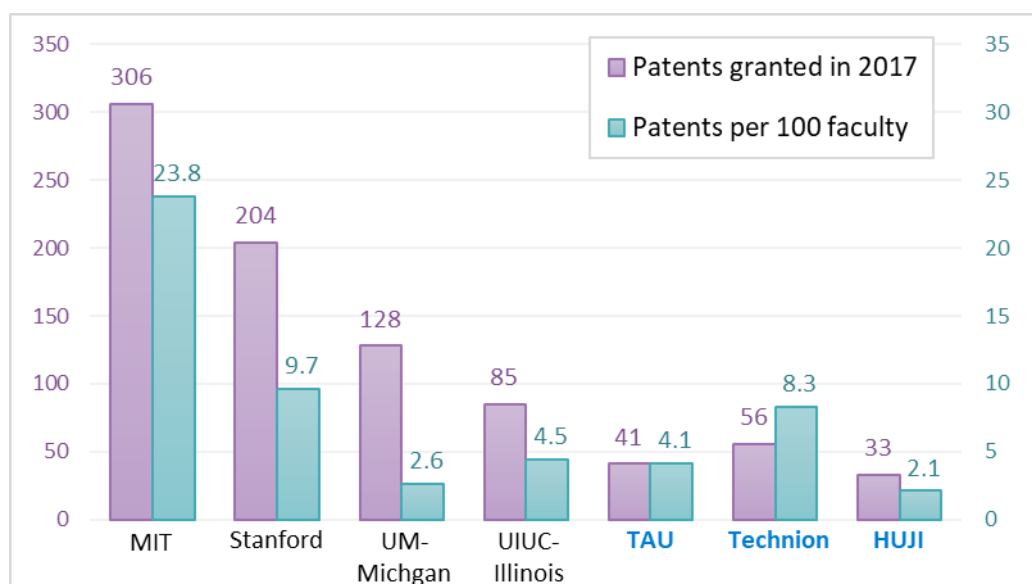
¹³ [Hugett 2014]

¹⁴ Data of Israel Central Bureau of Statistics

There is an interest in providing some insights of the nature of commercialization at universities having different characteristics, private universities that have large graduate programs to public universities where the bulk of students is at the undergraduate level. Seven universities were characterized by their patenting activity, presented in Figure 16 and Figure 17, based on data published for universities in the top 100 in the "Top 1000 worldwide universities granted US utility patents 2017" by NAI (The National Academy of Inventors) and IPO (Intellectual Property Owners Association).

Figure 16 presents the total number of patents granted in 2017 and the number of patents normalized for the size of the University, by calculating patents per number of faculty members.

Figure 16: Number of US utility patents granted in 2017 / normalized for the size of the university in terms of the number of faculty members ¹⁵



The data in the Figures is for leading US Universities (MIT, Stanford, UM-University of Michigan, UIUC-University of Illinois-Urbana Champaign, ranked 2, 4, 11 and 24, respectively) and leading Israeli Universities (Technion, TAU-Tel Aviv University, HUJI - Hebrew University Jerusalem, ranked 39, 64 and 82, respectively), the ranking being from the "Top 1000 worldwide universities granted US utility patents 2017" by NAI (The National Academy of Inventors). Two of the universities are private ones with high proportion of graduate students, Stanford (57% graduate students) and MIT (60% graduate students) and public ones where the proportion of graduate students is smaller, two US universities, University of Michigan (37% graduate students) and

¹⁵ For private universities having a high proportion of graduate students (MIT and Stanford) and public funded universities with high proportion of undergraduate students (University of Michigan – Ann Arbor, University of Illinois – Urbana Champaign, Tel Aviv University, Technion and Hebrew University)

University of Illinois Urbana-Champaign (26% graduate students) and 3 top Israeli universities with graduate students ratio between 1/4 to 1/3.

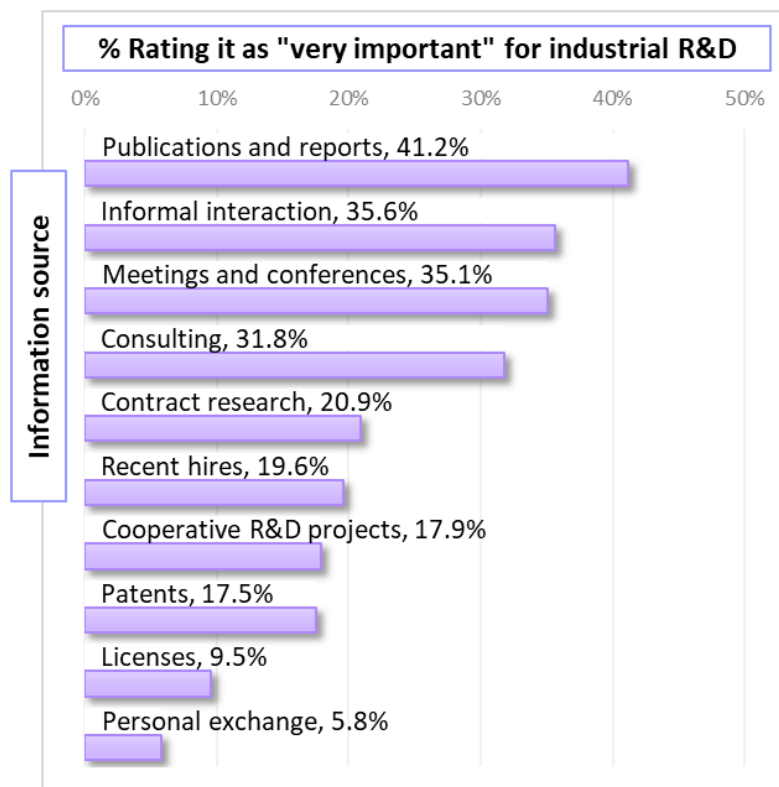
The data in Figure 16 clearly highlights the superior performance of the private US universities, much bigger than all the others in absolute as well as normalized values. The much better performance of the private US universities can be accounted for by their much higher proportion of graduate students (more than 50%) as compared to the public US universities and the Israeli ones. The US public universities perform better than the Israeli ones when the absolute values are considered, but after normalization, the Israeli universities are doing as well and even better.

4. Technology Transfer

4.1 Mechanisms

The flow of know-how from university research to industrial development and innovation has many avenues with considerable impact, as has, for example, been highlighted by [Cohen et al 2002] and quantified based on a survey of industries, Figure 17.

Figure 17: Importance to industrial R&D of sources of information generated in public R&D¹⁶



It can be seen that mechanisms which are defined as technology transfer in Figure 1 are relatively high on the list in Figure 17: informal interactions, consulting, contract research and cooperative R&D projects. They are much higher on the list than the Technology Commercialization mechanisms: patents and licenses.

Of particular importance are joint programs, sponsored by government to encourage collaborative research by university and industry scientists, in a variety of consortia mechanisms or one to one university-industry scientists. Such programs are sponsored by individual governments or international bodies like the EU in its framework programs. These are all within the concept of the triple helix model [Etzkowitz and Ledersdorff 2000].

¹⁶ After [Cohen et al 2002]

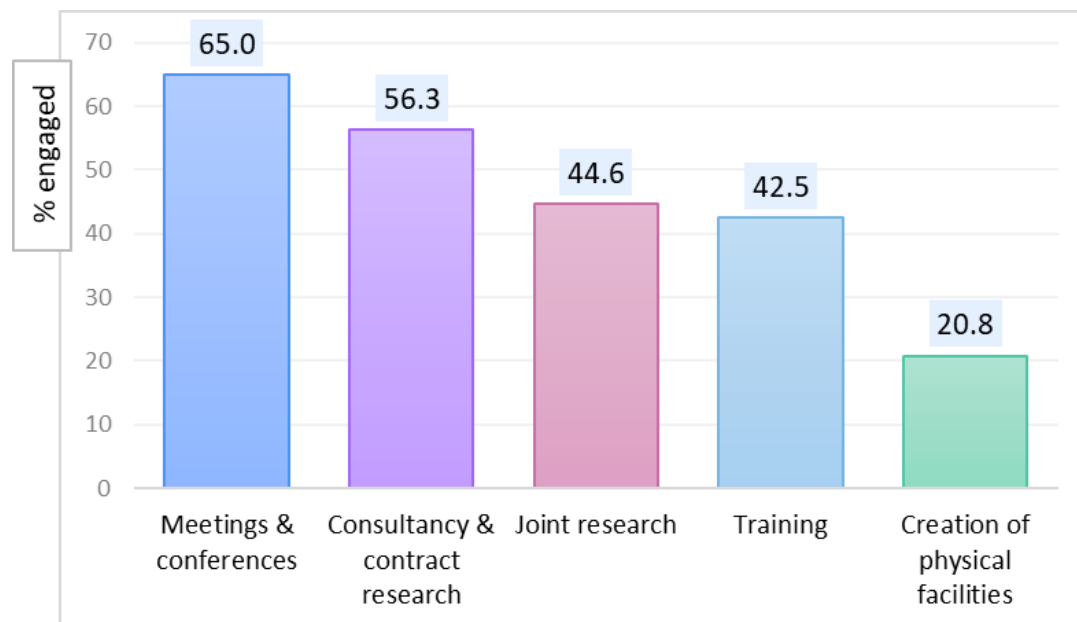
The impact of "Technology Transfer" mechanisms is largely indirect and the IP created is either jointly owned by the university and industry or industry only. This is in contrast with the "Technology Commercialization" mechanism where the output can be more readily quantified in terms of the number of patents, licenses and income. Thus, the quantification of "Technology Transfer" is based, usually, on inputs rather than outputs.

The impact of "Technology Transfer" is the result of many mechanisms, with some interacting with each other. Some are formal and can be readily identified, e.g. research contracts, and some are informal, driven by human interactions between researchers from the academia and industry who cooperate on specific research. Thus, there is a need to resolve such mechanisms first and thereafter to try quantifying them.

[D'Este et al 2007] identified five categories of university-industry interactions, as a basis for a survey of their significance. They include meetings and conferences, consultancy & contract research, creation of physical facilities (with industry funding, including laboratories, incubators and cooperative research centers), training (postgraduate training in companies and training of company's employees) and joint research (cooperative research by industry and academia).

The results of a survey carried out in the UK to resolve the significance of each of the categories is presented in Figure 18.

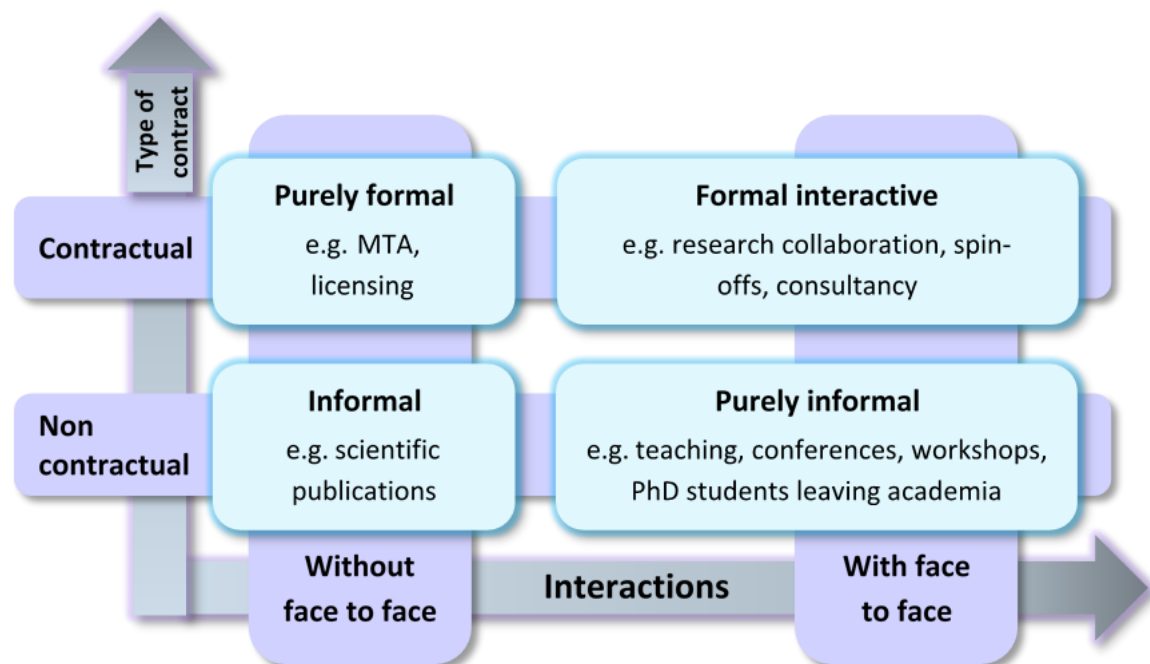
Figure 18: Involvement of university researchers in the five interaction categories (% of university researchers engaged at least once over the period in any of the interaction activities included in each of the five interaction categories) ¹⁷



¹⁷ Based on data of [D'Este et al 2007]

[Schaeffer et al 2018] investigated interaction mechanisms with the notion that there are significant informal interactions which have value and should be considered, and the presence of a contract, defining the formal relation, is not sufficient to evaluate the impact of the interactions. There are formal interactions which follow the linear model of innovation, where there is little surrounding tacit knowledge transfer, such as patent licensing agreements, and there are ones where continued and intense personal interactions may take place, such as in industrial research contracts, where face-to-face interactions are quite common. On that basis a broader classification was presented by [Schaeffer et al 2018] of formal and informal interactions, outlined in Figure 19.

Figure 19: Broad classification of formal and informal university-industry interactions¹⁸



They carried out an in-depth case-study of technology transfer in the pharmaceutical and robotics area, and presented the processes involved in terms of their nature and time frame, Figure 20 and Figure 21.

¹⁸ Based on concepts of After [Schaeffer et al 2018]

Figure 20: Micro-mechanisms of technology transfer - case study of technology transfer in the pharmaceutical field (labelled as "Prof. Pharma")¹⁹

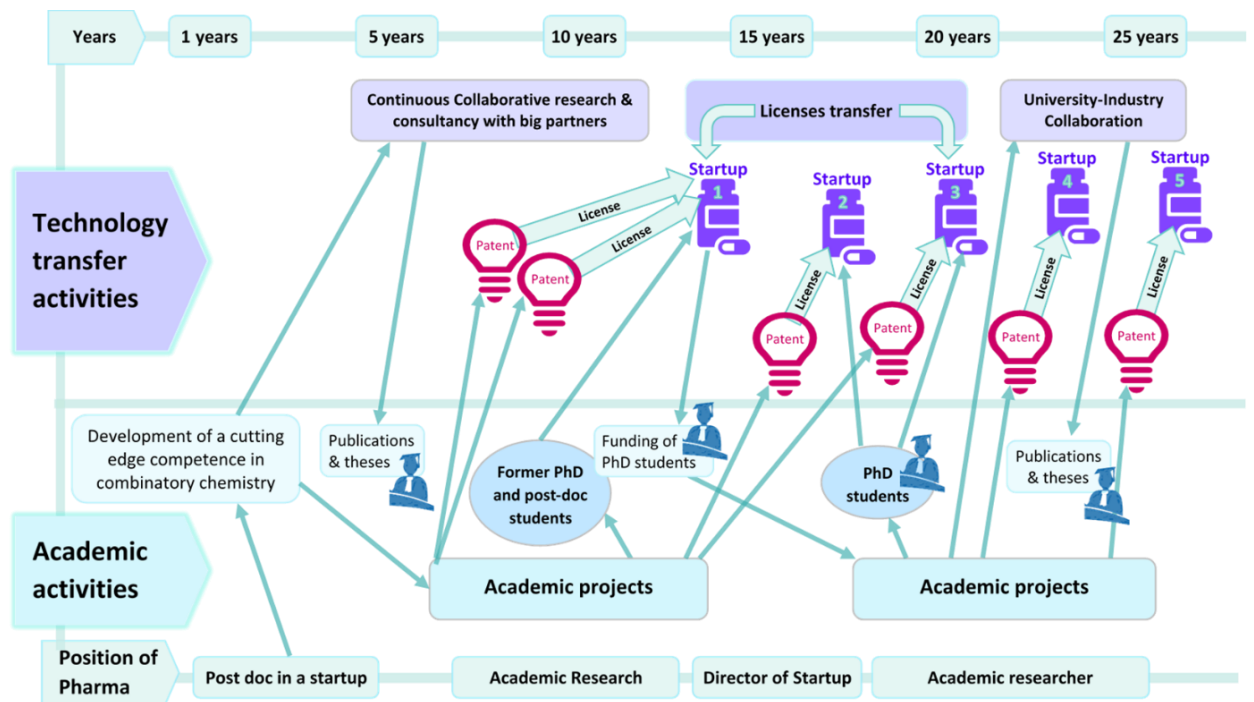
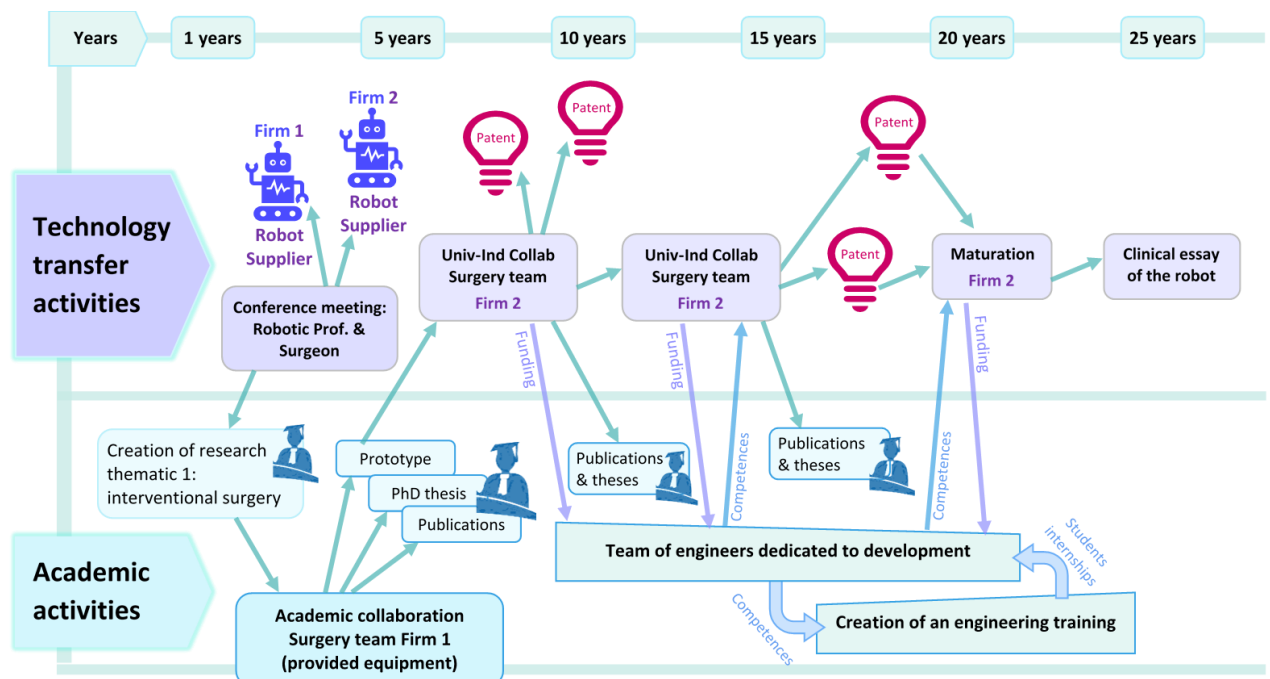


Figure 21: Micro-mechanisms of technology transfer - case study of technology transfer in the robotics field (labelled as "Prof. Rob")¹⁹



¹⁹ After [Schaeffer et al 2018]

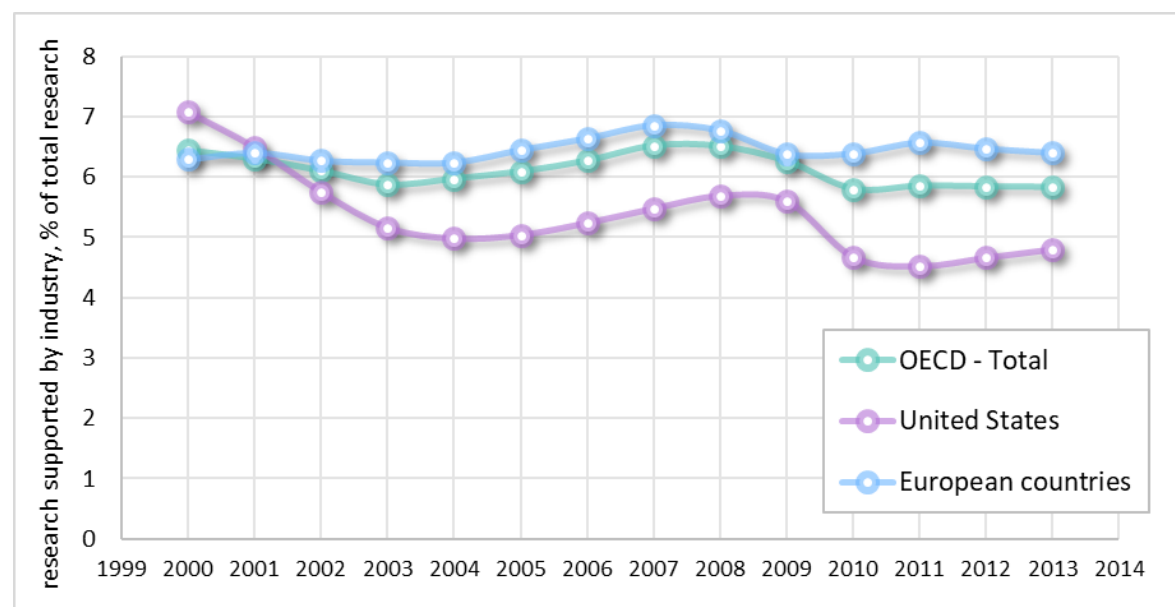
These case studies led [Schaffer et al 2018] to identify strong complementarities between the formal and informal mechanisms, which reinforce one another, consistent with the report of [Grimpe and Hussinger 2016]. Informal links often result in the establishment of formal interactions such as research agreements and startup formations. Formal relations are often followed by personal interactions which result in additional collaborations. It is the cumulative effects of these interactions which lead to efficient technology and knowledge transfer, and this is fed by good science and evolves into activities of mixed teams of academic and industrial researchers. In many ways this is an entrepreneurial activity whereby the University needs to develop wider strategies and modes of operation for its TTO/TLO, beyond the conventional mode of operation, where TTO/TLO staff is considered just as intermediaries in charge of patenting, licensing and establishment of new companies.

4.2 Quantification of the mechanisms

Various attempts have been made to quantify these mechanisms, each of them on its own, and a cumulative index incorporating all of them. Some examples highlighting different modes of quantifications will be presented here.

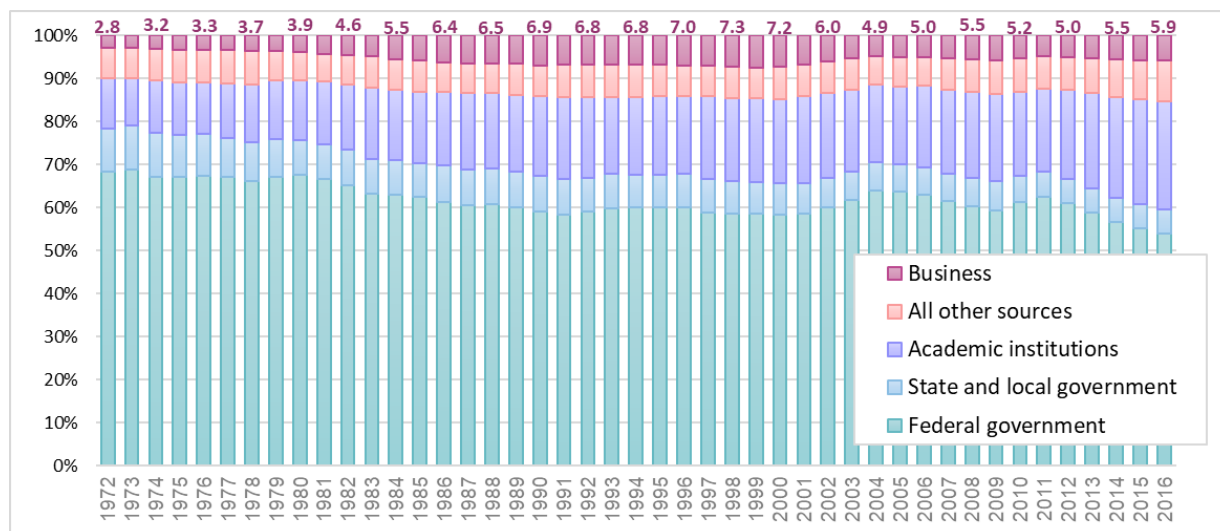
The most direct index to quantify the intensity of technology transfer associated with university-industry relations is the volume of research carried out by universities in cooperation with industry, based on industry funding. This is best described in terms of the proportion of research supported by industry relative to total research funding, Figure 22 using OECD data-base for OECD countries, US and Europe, since 2000 and Figure 23 for US since 1972, using NSF data base.

Figure 22: Proportion of research supported by industry in academia, average values in US, Europe and OECD countries²⁰



²⁰ OECD data

Figure 23: Proportion of research supported by industry in academia, average values in US since 1972 ²¹

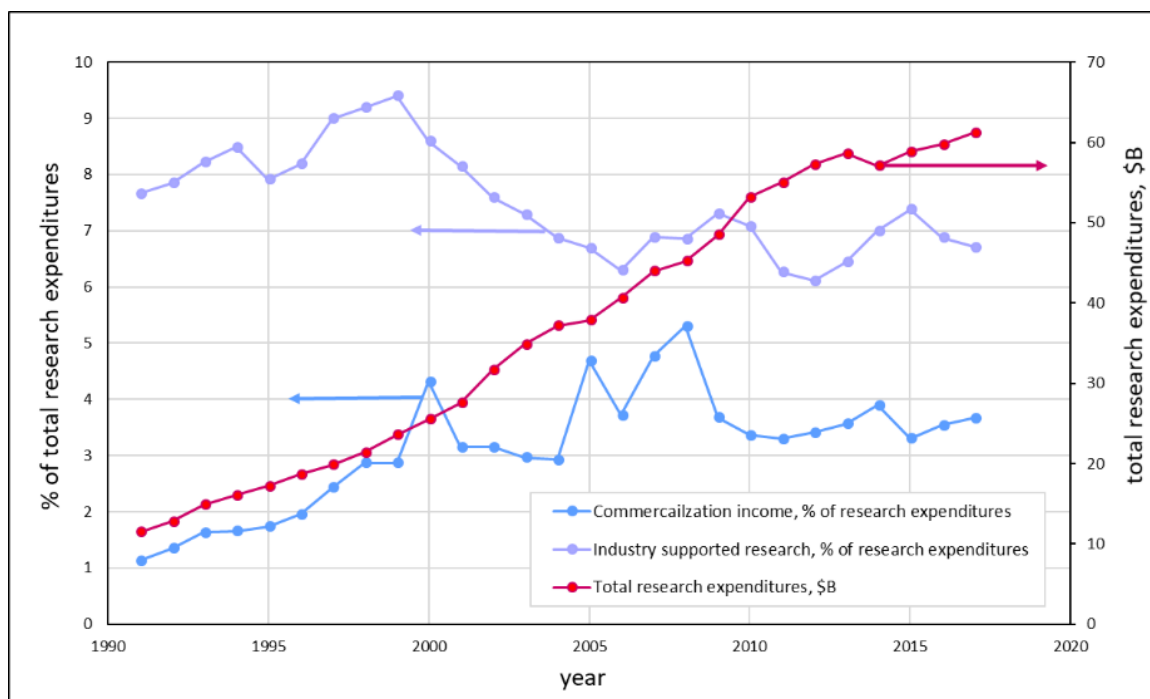


It can be seen, that over the period since 2000, the proportion of industrial funded research in academia has not increased and even showed slight decline, especially in the US. Data for longer periods for the US, starting 1972 (Figure 23), shows increase from 1972 till 1998 (from 2.8% to 7.3%) and decrease thereafter (from 7.3% in 1998 to 5.9% in 2016), Figure 23.

The trends for industrial supported research, commercialization income and total research funding for the US universities included in the AUTM survey (about 160 universities) are presented in Figure 24.

²¹ NSF survey

Figure 24: Trends of total research funding and relative research funded by industry and relative commercialization income for US universities reported in the AUTM surveys, 1991-2017²²

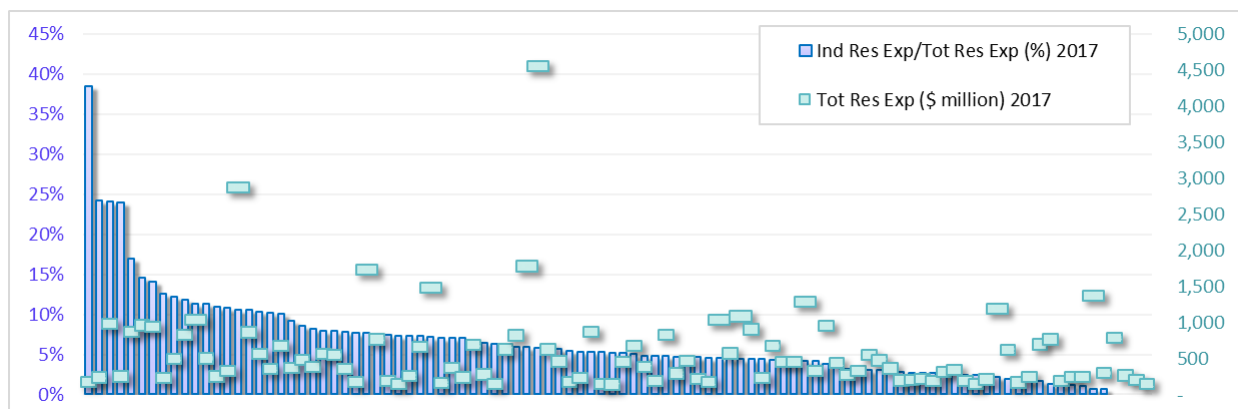


Total research funding has been increasing continuously over the years, however, the relative proportion of industrial funding has been decreasing while the relative commercial income seems to be stable since 2000, although very variable over this time period. Such trends imply that the intensity of technology transfer and technology commercialization since 2000 have been stable at best or even declining, contrary to the general belief that they have been intensifying. The trend of decline in industry supported R&D is similar in Figure 23 and Figure 24, yet the values are higher in Figure 24. This difference can be accounted for by the surveyed universities, 903 in the NSF survey of Figure 23 as compared to 160 in Figure 24, which make up the universities reporting to AUTM, which are probably the more active universities in technology transfer.

The distribution of relative industrial research funding in the top 100 US universities is shown in Figure 25, indicating very few universities with more than 10% industrial funding, falling quickly to levels below 10% for most universities in the top 100 list.

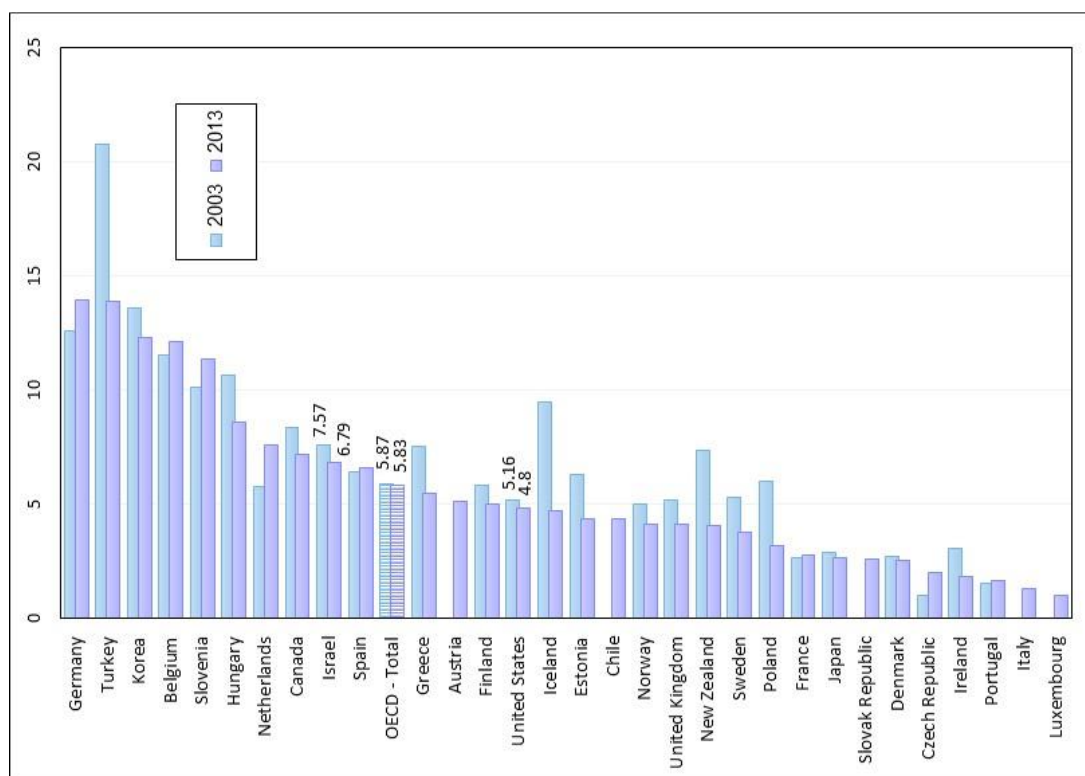
²² AUTM data, the number of universities surveyed increased from 72 to 115 during 1991 to 1993, thereafter increasing at a mild rate up to 160 in 2003, and from there on remained almost constant, to 163 in 2017

Figure 25: The distribution of the extent of relative industrial research funding in the top 100 universities in the AUTM survey



The distribution of industrial funding in academia in various countries is presented in Figure 26, showing that only in a few it exceeds 10%, and in most it is below 10%. The average for the OECD countries is slightly below 6%, and, as shown in Figure 22, it has been decreasing slightly over the years, somewhat above 6% in 2000 to slightly below 6% in 2013.

Figure 26: The distribution of the extent of relative industrial research funding in 2003 and 2013 in different countries, OECD survey ²³



²³ After [OECD 2016]

The trends above clearly highlight that the intensity of university-industry relations as quantified in terms of industrial funded research has not been intensified over the years, in spite of the national and international programs and policies to encourage more industrial research at universities.

Since industrial supported research is not the only mechanism for university-industry relations and technology transfer, it is of interest to explore and quantify other mechanisms.

[Tijssen et al 2016] defined 7 indices by which to characterize technology transfer and rank universities accordingly, Table 1.

Table 1: Indices for the quantification university technology transfer ²⁴

Index	Description
%UIC	Share of university-industry co-publications (as a % of research publication output)
%MA UIC	Share of multiple-affiliation university-industry co-publications with at least one author listing a university address and a company address (as a % the total UIC output)
%LOCAL UIC	Share of university-industry co-publications with at least one partner company within a 50 km range of the city in which the university is located (as a % the total UIC output)
%DOMESTIC UIC	Share of university-industry co-publications with at least one partner company located in the same country as the university (as a % the total UIC output)
%CO-PATENT	Share of granted international patents with a co-assignee from the business sector (as % of all granted international patents)
%NPLR Share	Share of non-patent literature references, i.e. publications cited in the reference list of international patents (as a % total research publication output)
%NPLR-HICI	Share of non-patent literature references within the world's top 10 % most highly cited international patents across all technology areas

Data sources used by [Tijssen et al 2016] to quantify these indices include:

- Leiden Ranking 2014 (publication years 2009–2012) for %UIC
- CWTS (publication years 2009–2012; Web of Science) for %MA UIC
- U-Multi-rank 2014 (publication years 2009–2012; Web of Science) for %LOCAL UIC
- UIRC Scoreboard 2014 (publication years 2009–2012) for %DOMESTIC UIC

²⁴ After [Tijssen et al 2016]

- U-Multi-rank 2014 (PATSTAT INCENTIM, Univ. Leuven; patent years 2002–2011) for %CO-PATENT
- U-Multi-rank 2014 (Web of Science; PATSTAT Univ. Leiden; patent and publication years 2002-2011; citing years 2002–2014) for %NPLR Share
- PATSTAT Univ. Leiden (patent and publication years 2002–2011; citing years 2002–2014) for %NPLR–HICI

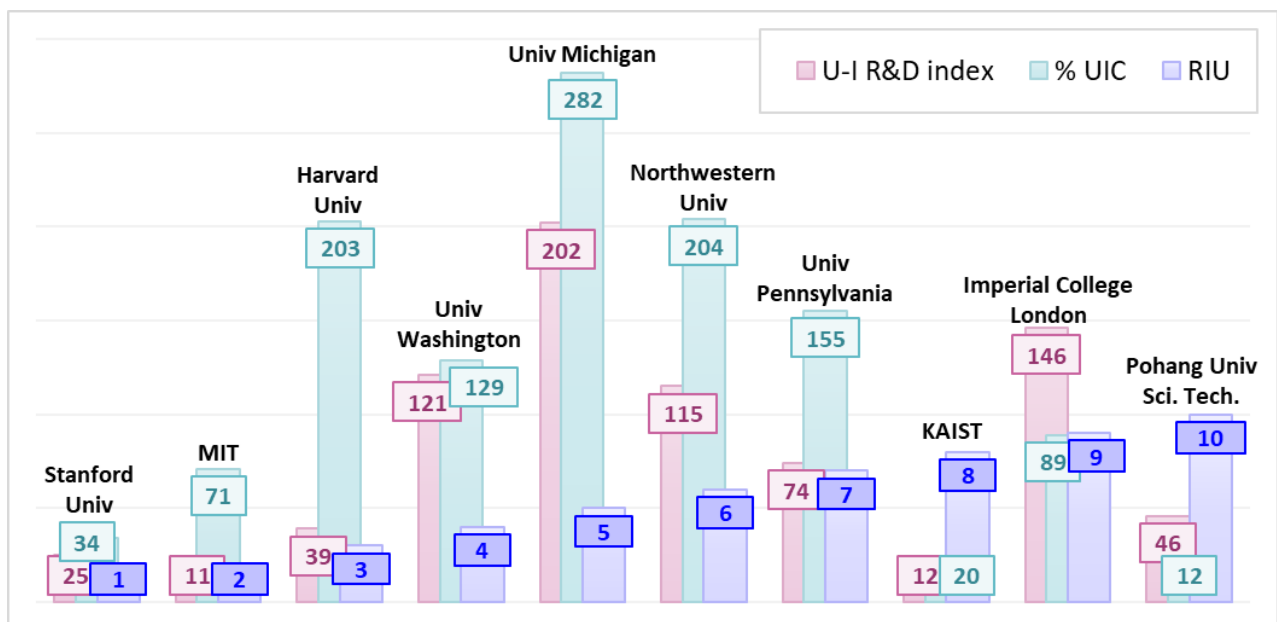
They analyzed several universities with an attempt to develop a comprehensive index which consists of some combination of the 7 indices in Table 1. One such index was obtained from the combination of the indices in the table, giving each of them an equal weight, labelling it as RIU – Equal weights index.

Statistical analysis could reduce or remove redundancies between the indices, where lower weights could be assigned to those that add little additional information. Such redundancies could be detected by applying statistical analysis to pairwise correlation coefficients between the selected metrics. Based on such analysis, different weights were assigned to the indices in Table 1, to define a single joint index based on non-equal weights using the following weights for the indices in Table 1:

%UIUC:	0.90
%MA UIC:	0.77
%Local UIC:	0.35
%Domestic – UIC:	0.60
%CO – Patent:	0.29
%NPLR:	0.74
%NPLR-HICI:	0.13

The index based on these weights is labelled U-I R&D Index

Ranking of selected universities, on the basis of these indices, is presented in Figure 27 based on the data base used for the indices in Table 1. The data in Figure 27 indicates that the universities can vary in the intensity of university-industry relation for the various mechanisms. This suggests that there is a need for a pluralistic approach which is not based on a single measure.

Figure 27: Rank positions of universities by various comprehensive indices ²⁵

RIU - Equal weight index

% UIC - Share of university-industry co-publications (as a % of research publication output)

U-I R&D index - Weighted average index

The need for a composite index taking into account the various mechanisms of technology transfer and commercialization was highlighted by the European Commission Expert Group on Knowledge Transfer Indicators [European Commission Expert Group 2011], outlining 3 types of indicators: Knowledge transfer through trained people (essentially similar to Knowledge Dissemination in Figure 1), Institutional co-operation in R&D and other phases of innovation (essentially similar to Technology Transfer in Figure 1) and Commercialization of research (essentially similar to Technology Commercialization in Figure 1). A comprehensive metrics approach along such concepts was developed in the UK for evaluating the performance of universities, based on an extensive list of mechanisms of technology transfer and commercialization, [Holi et al 2008], such as:

Indices for Technology Transfer:

- CPD - Continued Professional Development
- Consulting (number of contracts, income)
- Collaborative research (number of contracts, income)
- Industrial research funding (number of contracts, income)

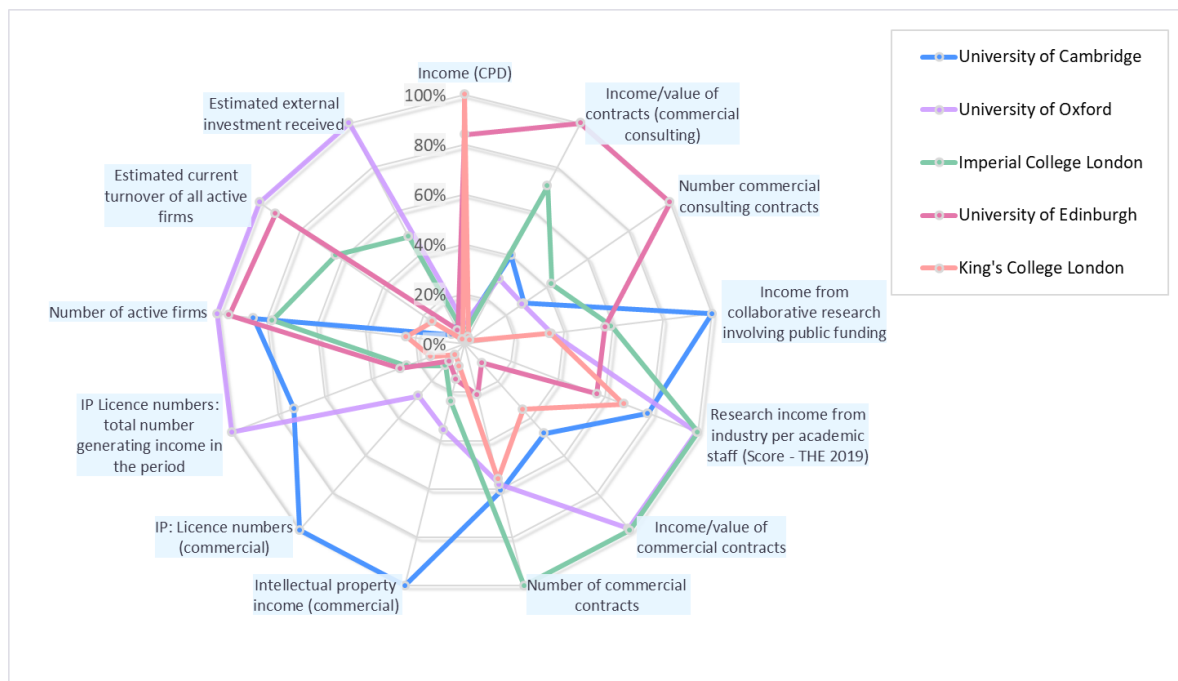
²⁵ After [Tijssen et al 2016]

Indices for Technology Commercialization:

- IP (income, number of patents and licenses)
- Startups (number, turnover, investment)

These indices and more are part of the indices used in the UK to evaluate and provide public support to universities for their knowledge exchange strategy within the framework of the Higher Education Innovation Funding [HEFCE 2016]. The data for such indices and evaluation is collected officially and presented by the Higher Education Statistics Agency (HESA). It is usually normalized to take into account the size of the university, and one of the common methods for normalization is to present the data per full time equivalent of academic staff, FTE, namely each value is divided by the FTE value. The availability of such data is used to characterize each university using a spider diagram, as demonstrated in Figure 28 for leading UK universities. The data is presented in terms of relative values for each index, with the university having the highest score in each criteria is taken as 100% and the others are presented in terms of relative value to this 100% score.

Figure 28: Spider diagrams comparing between performances of UK universities based on various indices (per FTE) describing each a mechanism of technology transfer and commercialization, presented as % of the university with the maximum index value for each index, demonstrating the concept for a sample of 5 selected universities, 2016/17 ²⁶



This UK approach seems to be quite a sensible one as it provides a comprehensive quantification of the technology transfer of different universities, and allows to resolve the differences in nature of such activities between the universities, identifying strength

²⁶ HESA data

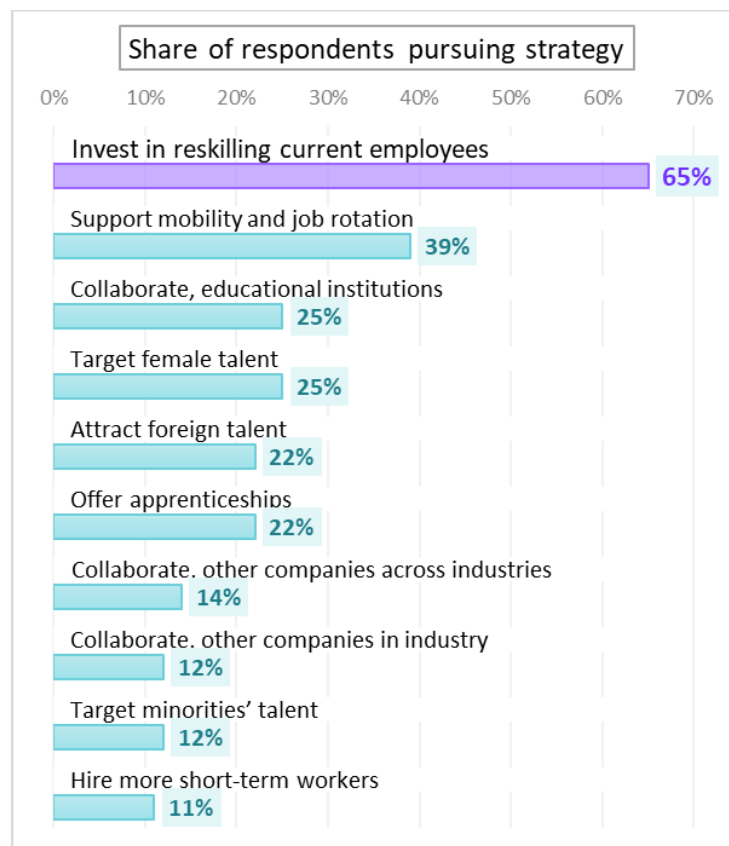
and weaknesses. It, also, allows to promote the notion that the view of technology transfer should be a pluralistic one, with each university seeking the path where it has special added value. Application of this approach requires that all universities apply a similar code of data collection and presentation.

5. Academia-Industry Cooperation in Engineering Education and Life-Long Learning

Traditionally, industry relied solely on academia to provide it with adequately educated engineers, with the implied assumption that engineering education responsibility lies within the domain of the academia only. In view of that state of affairs, some gap has been developing between the two organizations, industry and academia, with regards to engineering education, which is reflected in differing views on the expectations from newly engineering graduates. However, this situation has been changing, with industry realizing that it needs to provide some training to new engineering graduates before they can assume full responsibilities, and academia becoming apprehensive to the need to provide students with essential skills in addition to knowledge, and this requires some exposure to practice during their study-periods at the universities.

Recent survey of HR managers in industry highlighted that they perceive high on the list their responsibility to reskilling of the employees, which ties in with life-long learning, Figure 29 [WEF 2016].

Figure 29: The significance of HR strategies in industry ²⁷



²⁷ As observed in a survey by the [WEF 2016]

A study of the needs for modern engineering education in universities highlighted the need for new and revised paradigms, some of them requiring external reach to industry, as outlined in paradigm 5 in [Bentur et al 2018]:

Paradigm 5: Education of engineers should not take place only in the academia classroom and there is a need for cooperation with the industry for innovative models

Insights:

- *Holistic study program, with contribution of organizations and engineers acting as mentors throughout the professional life*
- *Incorporation of experts from industry in various mechanisms already during the academic study period: cooperation with industrial companies that employ engineers, to assure the relevance of the study programs for the development of skills required for the professional career, as well as enlisting the experts from the industry for project guidance and mentoring of students*
- *Intensify project-based learning*
- *Develop mechanisms for internships in industry, as part of study requirements*

The challenge of embedding skills with design and entrepreneurial mindset in engineering education is, thus, of a great challenge and perhaps the one where, on the one hand, innovation is needed, and on the other hand, its impact could be of great significance in reforming engineering education.

It is proposed that this would be one of the areas where unique contribution could be made by developing new platforms, which could be based on new concepts of university-industry cooperation. University-Industry cooperation is usually promoted with the view of research and technology transfer, but streamlining it to education could be much more "productive" in the value to be gained by the profile of engineering graduates: education combining fundamentals of engineering science with design and entrepreneurial mindset will result in engineers with technical and personal leadership qualities.

The current mode of operation of engineering departments is, in many respects, engineering science oriented, and the structure of programs and profile of the faculty is not favorable for the essential skills acquisition. It is unlikely to be changed in the foreseeable future, and there is an ongoing debate whether this is, overall, a desired change. With this in mind, and if greater attention to essential skills acquisition is to be promoted, there are several challenges which need to be considered:

- Acquisition of essential skills which will not be at the expense of core engineering science education
- Requirement for working in small groups in institutions where the ratio of students to faculty is high and unlikely to change drastically in the foreseeable future
- Profile of faculty which is scientifically oriented and adequate for engineering science education but not adjusted to acquisition of essential skills for industrial leadership and influence

A feasible and favorable mode of action to overcome these barriers can be based on more intimate cooperation between academia and industry, which can be developed

into a variety of practical mechanisms, provided that cultural adjustments are made in the academia and the industry:

- Understanding, in the industry, that it has responsibility and commitment to be a partner in the education process, based upon moral recognition and perception of the added value for the industry
- Recognition, in the academia, that cooperation with the industry is essential for development of students' essential skills, with the role of industry being more than just supplying experts to act as adjunct teachers

There are numerous models for cooperation which can be considered and developed, based on open attitude of the industry, to commit leading experts for mentoring roles and internships, such as: concentrated dedicated workshops in industry, promotion of interdisciplinary projects at universities, and encouragement of key personnel to accept professor of practice appointments in the universities for specified time periods, as part of their career path development at the industry. Complementary to that, the universities should be open to provide leading experts from the industry with academic appointments which will also enable the industry experts to have a say in the development of educational programs, and not just be positioned as adjuncts who come to teach already established courses or projects. The joint activities established may have added values beyond just the essential skills development and may be readily initiated and carried out within the framework of Entrepreneurial Centers which have been established in recent years in many universities, and are focusing part of their activities on education [Ndou et al 2018].

6. Societal Benefits

The analysis and discussion above indicates that the direct financial benefits to the university due to technology commercialization are small. This highlights the need to resolve whether there are societal benefits, to society at large as well as the university, in order to develop overall effective policies.

Societal effects are usually indirect in nature and their quantification requires, therefore, estimates based on a variety of approaches and assumptions [Drucker and Goldstein 2007] [Bronmann 2013] [Donovan 2011] [Petite 2004] [Salter and Martin 2001].

[Roessener et al 2013] presented such an analysis. They used an input-output (I-O) model to quantify two parameters:

- Change in gross output of all industries generated by university licensed products
- Impact on gross domestic product (GDP)

In their modeling estimates they presented a sensitivity analysis for different assumptions, average royalty rates in the range of 2 to 10% and 0, 10, 50 and 100% substitution rate of products and technologies based on university IP. For 2010 and for 5% royalty assumptions, the estimated change in GDP was 9.9, 8.9 and 4.9 Billions of Dollars, assuming 0, 10% and 50% product substitution rate, respectively. Taking the value of total research expenditures in Figure 24 as 53.2 Billion Dollars for 2010, the "apparent rate of return" can be estimated to be in the range of 9.3 to 18.5%.

[Mansfeld 1991, 1998] developed estimates for the rate of return based on a different methodology, and reported social return on university research as being 28%. [Petit 2004] reported rates of return in the range of 20 to 30% and [Salter and Martin 2001] a range between 21% and 67%. Such a large range reflects the fact that the rate of return cannot be measured uniformly or reliably.

[Goldstein 1995] and [Goldstein and Drucker 2007] have noted the need to bring into the estimate of societal parameters more than just the effect of technology transfer on gross industry output and increase in GDP, but also additional contributions which may be of equal or greater influence, such as:

- Generation of new knowledge
- Creation of human capital
- Transfer of knowledge by tacit means
- Regional leadership
- Production of knowledge infrastructure
- Influence on the regional milieu

Reviews focusing on engineering research centers by [Feller et al 2002] and [Roessener 2000], indicated that access of students and faculty as well as new ideas and research results have been more cited as benefits than technology transfer to members of engineering research centers.

In the discussion of societal benefits there is a need to consider the influences on the university itself to assess whether the focus on technology commercialization activities, benefits or detracts from other modes by which the university contributes to society in terms of its research and education. Input on such issues was obtained by [Love 2014] in a survey conducted. Some of the insights resolved are summarized below:

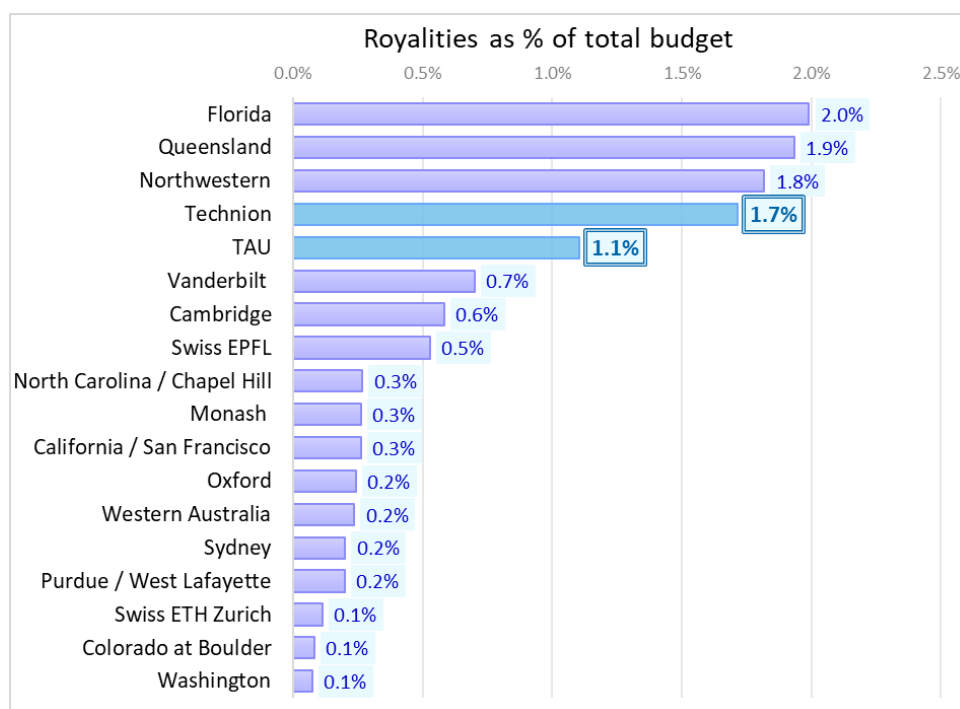
- Patenting high-tech inventions made on university campuses may not be a profitable undertaking, even at those universities best-positioned to profit from commercialization of technology. Based on the patenting and licensing activities of the survey, [Love 2014] estimated that university patent programs collectively earn a negative rate of return—an overall loss of more than three percent—on funds invested in high-tech patenting.
- The prospect of obtaining patent rights did not appear to motivate university researchers in high-tech fields to conduct more or better research. Eighty-five percent of professors reported that patent rights are not among the top four factors motivating their research activities.
- University patent programs may actually reduce the quantity and quality of university research in high-tech fields by harming professors' ability to obtain research funding, to collaborate with faculty from other institutions, and to disseminate their work to colleagues.
- University patent programs seem to be, at best, a modest benefit to professors seeking to commercialize high-tech academic research. Entrepreneurial professors report that these programs hinder their ability to work as consultants with companies that show interest in their research, and fewer than half of university spin-off founders report that the ability to patent their research affirmatively helped their commercialization efforts.

7. The Israeli Perspective

This report is intended, also, to serve as a basis for brainstorming in Israel with regards to policies for technology transfer and commercialization. There is, thus, interest to compare the performance of some of the Israeli universities with ones abroad, and resolve whether the trends observed on the international level are valid for Israel. Comparison of that kind is not simple, as there is a need to look for indices for which the data assembled is based on similar premises.

The range of royalties received in leading Israeli universities is compared with several international ones in Figure 30. The data collected was for universities in the first 100 ranking of the Shanghai list, for which financial statements could be found. The royalties are presented in relative terms, % of total budget of the university.

Figure 30: Relative income from IP commercialization, % of total university budget, 2017 ²⁸



It can be seen that for the two Israeli universities where data was available, Technion and Tel Aviv University, the performance is comparable to leading international universities. Yet, as already observed previously, the commercialization income is extremely small even for the highest values in Figure 30.

The number of startups established by leading Israeli universities is comparable to international universities, especially when normalization for the size is made, based on number of faculty members, Figure 31 and Figure 32.

²⁸ Of universities in the top 100 ranking Shanghai list, for which financial statements could be found over the internet

Figure 31: Startup established during 2007-2016 for selected universities, sources: AUTM for US universities, IVC for Israeli universities

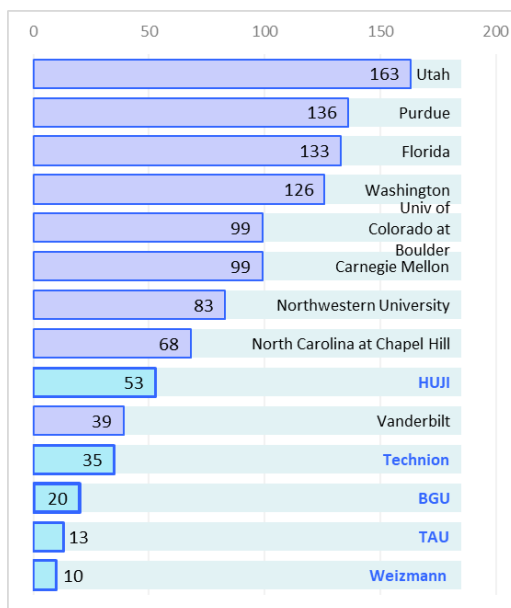
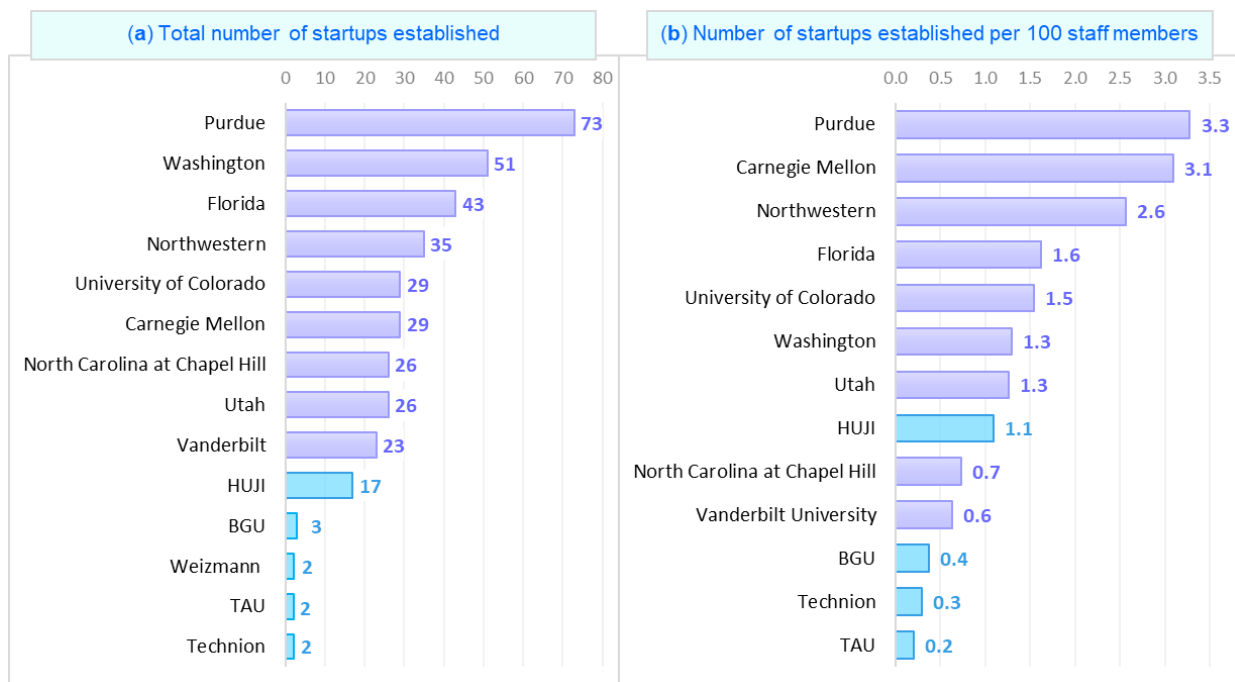


Figure 32: Startup established during 2015-2017 for selected universities, (a) total, (b) normalized for the number of faculty members ²⁹



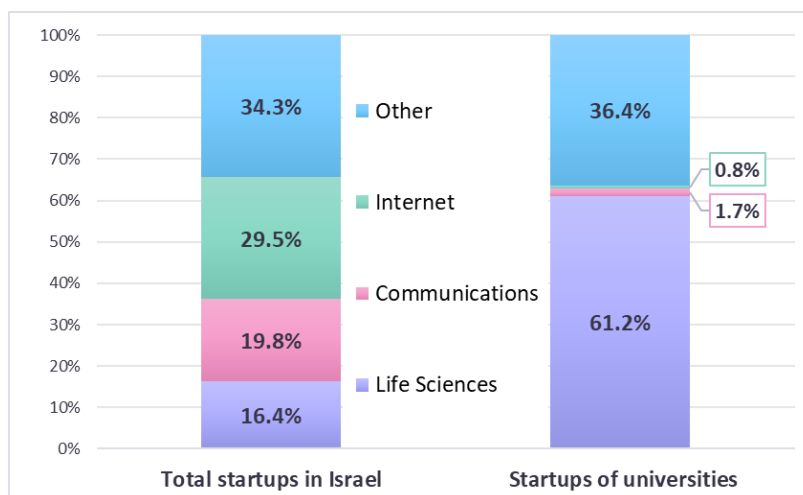
²⁹ Sources: AUTM for US universities, IVC for Israeli universities.

The data in the figures is for universities included in the Times Ranking; since the Weizmann Institute is a research institute it is not included there

The normalization for the number of faculty members is based on data in Times World University Rankings 2018 ([website](#))

The professional activity of commercialization in the Israeli universities is, to a large extent, in the life sciences, Figure 15, similar to international universities, Figure 14, but quite different than the overall startup activities in Israel, outside universities, which is focused currently on ICT, Figure 33.

Figure 33: Professional distribution of startup activities of universities in Israel, compared to the overall professional activities, 2002-2015



The geographical distribution of the startups established by Israeli universities clearly shows the proximity preference to remain in the zone of the university, Figure 34. Since some of the bigger universities are in the peripheral areas of the country (Technion and Haifa University in the North, Hebrew University in the Jerusalem area, and Ben Gurion university in the South) there is a tendency for peripheral concentration of their startups, in contrast with the distribution for startups at large, where there is a relatively small presence in the periphery, Figure 35.

Figure 34: Geographical distribution of startups established by Israeli universities, % remaining in the geographic zone of the university

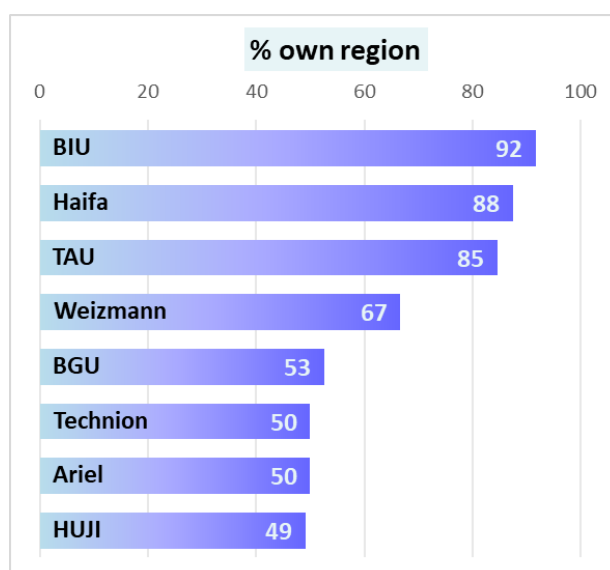
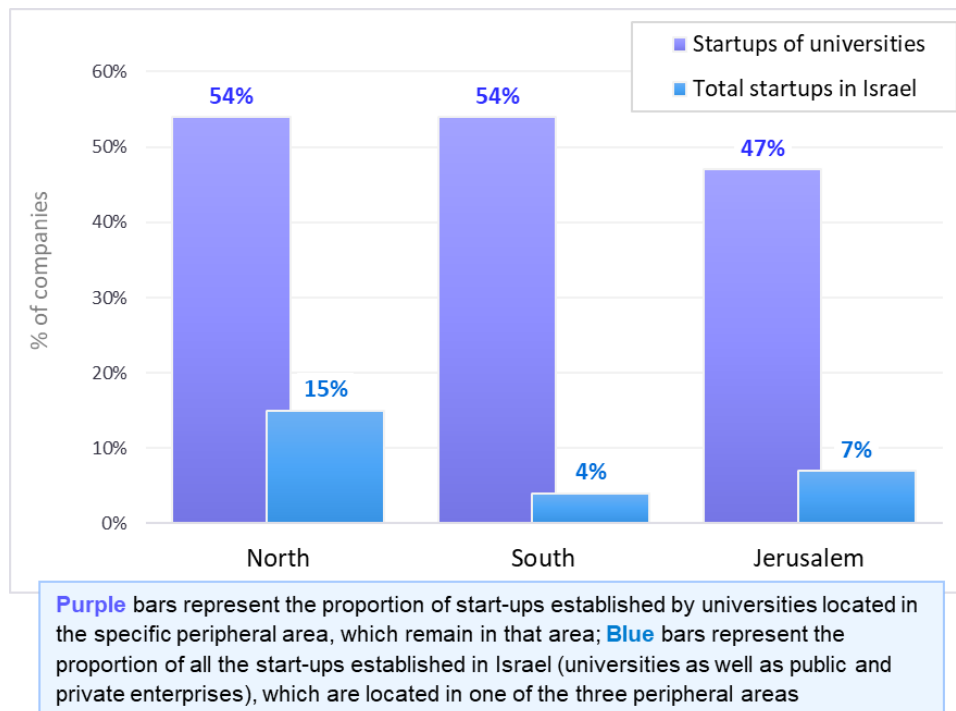


Figure 35: Geographic distribution of startups established in Israel, by TTO's of universities and et large



In order to gain some perspective of the benefits of the universities' activities to the Israeli industry, interviews with 20 key industrial leaders were carried out. The main issues highlighted by the interviewees are presented below. It should be noted that most of the interviewed addressed issues of education of engineers and scientists at the universities and their preparedness for industrial employment, which seems to be their main interest in universities.

- The industry views the academia first of all as the "supplier" of human resources, namely engineers and scientists which should be highly qualified for their employment in the industry.
- Some companies are ready to provide equipment and infrastructure for students' exercises and lab projects to bring them closer to "real" systems.
- Some of the interviewed took for granted the current curriculum of education of scientists and engineers at the universities and take the position that it is their commitment to carry on additional training; some expressed the need to have an influence on the educational programs at the academic institutions.
- There was interest in setting up joint task groups to assess the educational needs.
- Some felt that the academia overlooks the industry, believing that academia "knows better" the educational requirements; they believe that if the academia wants to be relevant it should be more open for the needs and ideas coming from the industry.
- Most interviewed expressed favorable attitude for employment of students in the industry during their study years; on that basis they highlighted the need for cooperation between academia and industry to adjust the expectations from students' employment.

- In some of the industrial companies there is efficient cooperation with faculty in conducting joint researches; this is mainly associated with a match between the academic and industry scientists and finding ways to by-pass the rigid IP protection policies of the universities.
- Nowadays, there is less consulting of faculty in the industry and smaller participation of experts from industry in teaching, than used to be in the past.
- Many had good words to say about the role of the innovation authority and especially the various consortia models which allow to overcome IP barriers for the cooperation.
- The issue of university policies on IP was brought up consistently as a barrier for cooperation, resulting in industry shying away from sponsoring research in the universities.
- A great potential for research cooperation is lost because of the barriers posed by the TTO's and lawyers, reducing the motivation of industry to deal with TTO's and fund research at the universities.

8. Policy Implications: Technology Transfer vs. Technology Commercialization

8.1 Income Generation vs. Technology Diffusion

The high-profile attention given to technology transfer of universities is mainly focused on the commercialization efforts, i.e. to the "technology commercialization" defined in the current report. Policies developed for university technology transfer are, thus, based on a view which is related to "technology commercialization" whereby special attention is given to IP protection and income generation. The question arises whether this is, indeed, the right way to go from the point of view of societal benefits which can be generated by universities with respect to promotion of the economy and industry by being pro-active in mobilizing the university newly developed know-how.

Optimization of "technology commercialization" policies is often the main driver for TTO/TLO's existence. It is largely driven by the attempt to maximize revenues for the university and with this goal in mind, IP protection policies are being developed. However, the data presented in chapter 3 suggest that the income received is relatively small. [Merrill and Mazza 2011] reported that the average "rate of return" on funded research to be 4.1% and the median is 0.9%.

More than that, estimates of the net income from commercialization, after considering the expenses involved, such as staff of TTO and patent expenses, suggest that out of 155 TTO's reporting to AUTM, 130 did not break even and were at a loss; it is estimated that over the last 20 years 87% of the universities did not break even [Valdivia 2013]. This is further echoed by [Love 2014], based on a survey which concluded a negative rate of return (e.g. loss of about 3%), and similar trends reported by [Thursby and Thursby 2007] based on surveys.

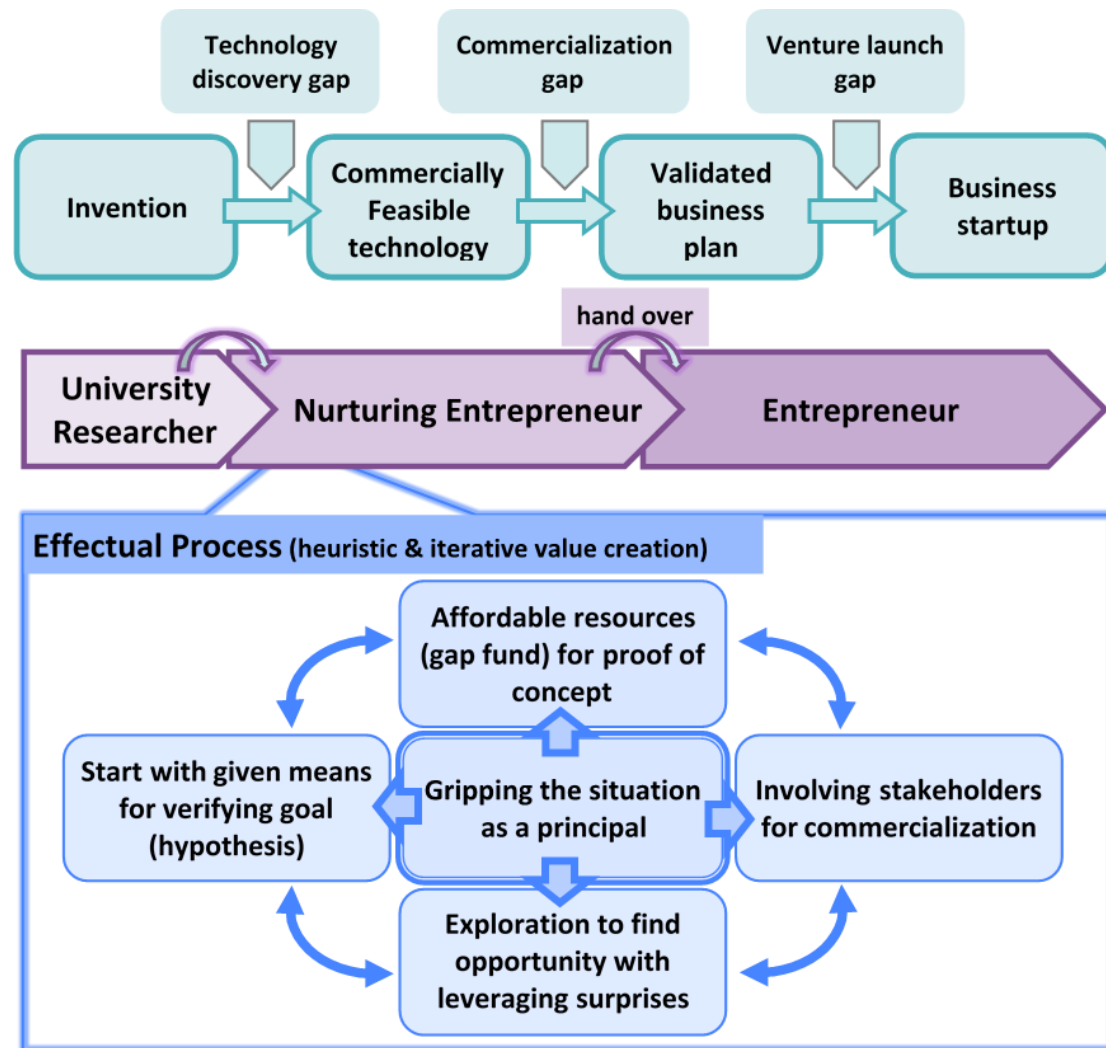
These gloomy trends seem to have remained approximately constant over most of the last two decades.

The impressive values of above 10% income from commercialization, relative to R&D expenditure, are those of very few universities which seem to have had blockbusters. It was shown (Figure 13) that the probability for a blockbuster drops drastically beyond the 10 top ranking university research funding, being 30% chance at the 10th, 12% at the 40th and 5% at the 100th. The analysis by [Valdivia 2013] in Figure 13 is consistent with survey of universities and business reported by [Thursby and Thursby 2007]. It has been suggested that this state-of-affairs is at least in part due to the fact that most university licensed inventions are at a very early stage, either proof of concept (no prototype) or prototype (only lab scale). This is echoed by the input of the business survey which indicated that university inventions had a higher failure rate than inventions from non-university sources.

Similar view was aired by [Takata et al 2018], suggesting that the TTO/TLO should take, also, additional responsibility in the innovation pipeline by being pro-active in establishing a bridge to bring technology into maturity, to make it ripe for commercialization, as shown schematically in Figure 36. They labelled this additional

role of TTO as "Nurturing Entrepreneur". This is consistent with Accelerator and Proof of Concept programs [Munari and Toschi 2019].

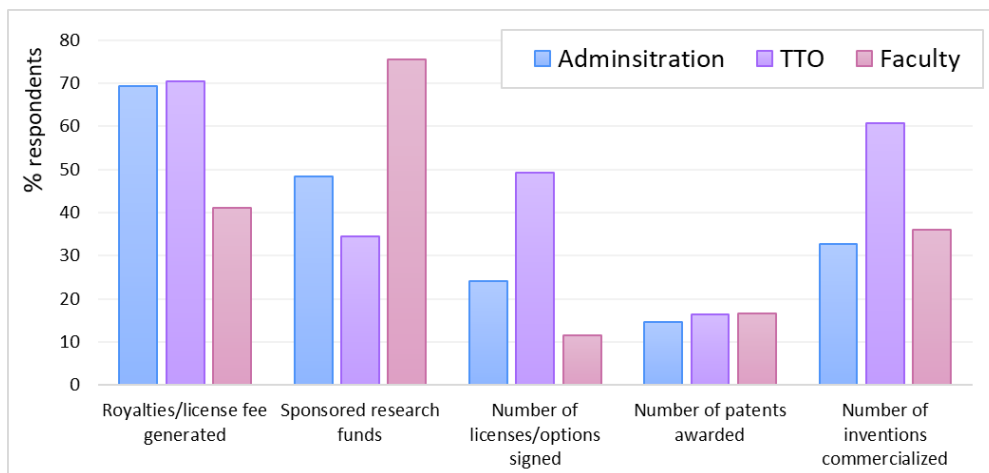
Figure 36: Characteristics of the technology transfer process, highlighting the need for an additional role of TTO in the establishment of commercial feasibility by activities of a "Nurturing Entrepreneur" ³⁰



[Thursby and Thursby 2007] discussed several issues in view of the limited or negative financial gains by licensing and based their analysis on responses to surveys they have taken, Figure 37. Most important was the input of the university stake holders with regards to the goals of technology transfer: Administration and TTO/TLO officials see it as highly important while faculty take the position that financial gains is not the only goal, as seen from the importance of indicators to success, highlighted by respondents in Figure 37. The opposite is the response to the issue of sponsored research funds: faculty see it as highly important while administration and TTO/TLO officials place it as mildly important.

³⁰ [Takata et al 2018]

Figure 37: Assessment of the significance of licensing success by the three stakeholders in university: TTO officials, faculty members and administration (% of respondents who indicated "extremely important") ³¹



In the consideration of faculty perception there is a need to take into account the variability of the faculty personality and attitude. [Lavie 2019] suggested to approach the faculty taking into account three different profiles: (i) faculty who have the entrepreneurial intentions as well as the skills and can proceed in realizing the potential of their invention on their own, (ii) faculty who have no interest in entrepreneurial activities to develop further their inventions and prefer to let the organization to proceed with it without their intervention, (iii) faculty who have entrepreneurial aspirations but do not have entrepreneurial skills, who want to lead the application of their inventions in spite of their lack of the capabilities needed. The policies for the first and second group should be quite different, while the third group, is the most problematic. Consideration of these differences suggests that flexible policies need to be developed, and the TTO/TLO should be autonomous in implementing them considering the profiles of the faculty members.

8.2 New Policies and TTO/TLO's Missions

This state of affairs requires to consider the strategy of the university with respect to maximizing its income. Increasing the chances for a blockbuster might be achieved by several means such as redirecting and focusing the research into the most attractive fields for emergence of a blockbuster and motivating faculty by providing special incentives for promotion. These, however, will probably be met with strong internal resistance as well as risk of jeopardizing other university goals.

In view of such insights, new ideas about strategies have been emerging. [Valdivia 2013] discussed alternative strategies to manage IP. He emphasized that university patents are usually breaking new grounds and only a small number of people can understand their potential. It is thus relevant to consider giving greater emphasis to

³¹ Adopted from [Thursby and Thursby 2007]

establishing startups and redirecting resources of TTO/TLO to this kind of model. It requires creating incentives and organizational capacity. This mode of action is, also, consistent with a move to create an ecosystem within the university as well as support regional development and provide more fruitful interaction with the community. On that basis Valdivia made several policy recommendations:

- Government should provide more funding to Small Business Technology Transfer (STTR) programs, designating funds specifically for university startups.
- Congress should authorize a patent use exemption for non-profit research organizations for exclusive experimental use. Enable federal agencies to use march-in rights under the Bayh-Dole Act to extend non-exclusive licenses for research tool patents that have been subjected to pricing excess.
- Create an equity rule for the distribution of funds among universities.

[Hugett 2014] also highlighted the significance of the startup model, especially under the special conditions of the bio-tech field, where there is increasing number of doctorate graduates and a gap which is growing between these numbers and the available academic positions: the number of PhD's awarded from 1980 till 2010 was about 35,000, while the number of academic positions opened over this period was about 5,000.

These changes have sparked interest in startups by faculty as well as new PhDs. [Hugett 2014] addresses this change and the potential environment for it as a move of TTO/TLO from "dog and pony show" to actively seeking partners for university research assets.

Additional ideas and review of several models of the mode of operation of technology transfer units have been reported by [Allen and O'Shea 2014]:

Gateway approach: intended to minimize obstacles for commercialization by joining together of the offices dealing with research, contracts, technology transfer, relations with industry and support for entrepreneurship. This joint unit assures the stream-lining of relations with the various "players" over the inclination for short term profit. In this model it is assumed that the significant income will be obtained over a time period, when successful entrepreneurs will support research at the university on top of donations.

Centric approach: In this mode the university develops long term alliance with experts in commercialization and IP to get into the market attractive ideas. In Europe, an organization called IP Group developed partnership with 12 UK universities, including Oxford and Kings College. It generated more than 100 companies of which 15 reached IPO.

Academic Entrepreneurship Model: In this model, adopted at MIT, the office of technology transfer is actively participating in setting relations between faculty members and VC and allows them to advance in the entrepreneurship process. The university gets a small share and the TTO is not involved in running the process. The emphasis is on getting a process going and making an impact on the community.

Easy Access IP Model: The model was developed in Europe and it provides the IP freely. It does not allow for income to the university but enables a great deal of

inventions to reach society. As the emphasis is on impact, the university hopes to generate sources for financial support of research with the growth of companies based on this IP.

The best model depends on the university. [Allen and O'Shea 2014] claimed that most technology transfer offices are not meeting their goal of dissemination of innovation, and therefore, universities have to re-evaluate their mode of operation with the view of making greater impact on society rather than direct income.

8.3 IP Protection Policies and the Bayh-Dole Act

In view of this state of affairs there is considerable debate whether there is a proper balance in university policies and mode of action of TTO/TLO, between technology commercialization and technology transfer. This has been echoed in several reviews of the developments following the Bayh-Dole Act of 1980, questioning whether universities have overemphasized technology commercialization which takes place largely by the "linear model", at the expense of technology transfer, which is more likely to promote interdisciplinary activities made up by groups of scientists from the academia and industry working together.

[Sampat 2006] stated that the purpose of the Bayh-Dole Act was not to provide revenues to the universities or change the nature of the research from basic to entrepreneurial and applied, but rather to encourage technology transfer to the industry and private sector, which could be developed from basic-academic research that was not commercially oriented. Since the technology transfer from university is taking place by several modes, in addition to patenting and licensing, it is essential to evaluate the effect of the Bayh-Dole Act by considering the whole array of mechanisms. There is a need to resolve whether the patenting and licensing is related or affects the other channels of technology transfer, especially in view of their significance. The issue is whether the changes with regards to patenting affected the traditional mode of knowledge transfer such as publications, conferences, and informal channels. There is the question whether universities are patenting "science" rather than embryonic technologies. The societal costs and benefits of the Bayh-Dole Act depend less on whether university research is patented or not, but more on how it is licensed, which is the policy issue which needs to be addressed.

From a societal point of view, one would like to patent public funded university research output only in the case that without it the research output would not be effectively utilized. Also, exclusive licensing should be granted only when non-exclusive one will not enable commercialization.

It is, thus, best if Universities take at their initiative steps for managing patenting with the perspective of the public interest rather than their own financial interest. Consideration for changing the current model of IP ownership which follows the Bayh-Dole Act was suggested by [Kenny and Patton 2009], Table 2.

Table 2: Comparison between different models of IP ownership ³²

	Bayh-Dole (current model)	Inventor ownership model	Weak ownership rights model	
			Non-exclusive license variant	Public domain variant
Locus of decision making	TLO (centralized)	Inventor (decentralized)	TLO (centralized)	Not applicable
Technology diffusion	TLO has total control. Performance determined by TLO's knowledge, capability, and institutional issues.	Inventor chooses channels based on their knowledge and capability. Can contract for assistance.	Operates as tax on users. If sufficiently low may have no impact.	Freely available but no direct incentive based on ownership.
Income	TLO responsible, captures income, and shares with various stakeholders. Income can be great, in certain cases, but usually small.	Inventor captures all (though possible to provide university with automatic share).	Can be great with fundamental process innovations, but could diminish for products benefiting from exclusivity.	Not applicable
Local economic development	Licensing bias toward to large firms that are often not local.	Indeterminate, if inventor commercializes likely to be local.	Only local advantage is proximity to inventor, but large external firms have access.	Only local advantage is proximity to inventor, but large external firms have access.
Inventor conflict of interests	TLO has responsibility, university admin financially interested party.	University admin not financially interested party.	TLO has responsibility, university admin financially interested party.	Not applicable
Adversarial TLO-Inventor relations	Good TLOs minimized, Bad TLOs many.	Fewer as the relationship is now voluntary.	Good TLOs minimized, Bad TLOs many.	Not applicable
Adversarial Licensee-TLO relations	Good TLOs minimized, Bad TLOs licensees may refuse to participate.	Indeterminate but relations are decentralized.	Good TLOs minimized, Bad TLOs licensees may refuse to participate.	Not applicable

Some insight on the impact of IP protection policy might be gained from a study by [Valentin and Jensen 2007]. They compared technology transfer in Denmark, where a

³² [Kenny and Patton 2009]

law similar to Bayh-Dole Act was enacted (Danish Law on University Patenting – LUP), to Sweden where the traditional European policy of academic researcher ownership of IP was maintained. It was concluded that the LUP resulted in moderate increase of inventions channeled through university owned patent system, but the larger part of the inventive potential of the academia, previously mobilized into company owned patents, seems to have been rendered largely inactive as a result of the law. A likely explanation is that exploratory research, which is usually a target in University-Industry joint projects, especially in bio-tech firms, matches poorly with LUP IP requirements: The pre-LUP system, allocating IP rights to the industrial partner in return for research funding and publication rights to the academic researcher, may have offered more effective industrial contracting for research. It is concluded however, that LUP is not uniform in its effect on joint university-industry research: it will operate better for joint R&D issues closer to commercial technologies, exploitive research, but less well for explorative research.

In the consideration of the overall range of technology transfer, [Link et al 2007] resolved between formal and informal technology transfer mechanisms. Informal mechanisms facilitate flow by communications, such as technical assistance, consulting and collaborative research, in which IP rights play a secondary role. Formal mechanisms are based to a large extent on allocation of property rights. Based on their work and review of others, [Link et al 2007] [Siegal et al 2004] [Link and Siegel 2005] [Lach and Schankerman 2004] [Friedman and Silberman 2003], they pointed out the dis-satisfaction of faculty members across universities with the formal mechanism, citing issues such as insufficient royalty allocation to faculty members, heavy bureaucracy, high rate of turnover among licensing officers, insufficient professionalism of TTO/TLO. The latter was highlighted by [Hertzfeld et al 2006] who interviewed legal consultants of industry and found that many of them had difficulty in dealing with TTO's/TLO's mainly due to inexperience and lack of business knowledge of their staff. [Link et al 2007] concluded that faculty members may have a strong interest in the informal mechanisms.

The survey carried out by [Link et al 2007] indicated that faculty members who are active in securing research grants are preferring the informal modes of technology transfer. This may imply that there is tension between the grant-active faculty and university incentives to take part in formal technology transfer modes, perhaps because the former are more basic in nature and the latter more applied.

[Markman et al 2008, 2004] looked into the complex relations between faculty members, TTO/TLO and university administrators in the context of by-passing the TTO/TLO. The survey indicated that 42% of the scientists who invent patents by-pass their university and over 33% of the patents that originated from universities were appropriated privately. They discussed the effect of limiting the contacts between faculty members and industry in the context of negative externalities with regards to inefficient knowledge spillovers. A large sample of 23,394 scientists from 54 universities was evaluated, to assess a mode in which the university is the principal (owner of IP) and the TTO/TLO and scientists are agents. They considered several factors, formal and informal institutional rules, the general ethos of agents involved in the business activity, incentives, normative expectations, organizational design, and the context in which agent-contracting takes place.

Their study showed that by-passing activity is reduced when universities rely on autonomous and highly professional TTO/TLO's and when faculty receive greater shares of the royalties. Conversely, by-passing activity is increased with more valuable discoveries and when enhanced entrepreneurial activities take place on university campus.

9. Insights

National policies for IP protection of university know-how were established with the view that this is an effective mechanism by which universities will be encouraged to be pro-active in transferring their know-how to industry to facilitate national economical and societal benefits. This is consistent with the "third mission" of universities [Zomer and Benneworth 2011] as addressed already in chapter 2 of this report. The Bayh-Dole Act of the 1980 in the US, which is considered as a corner stone of these policies, was enacted with this spirit, as is evident from the preamble of the act sets out Congress's objectives [Miller 2005]:

"It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development; to encourage maximum participation of small business firms in federally supported research and development efforts; to promote collaboration between commercial concerns and nonprofit organizations, including universities; to insure that inventions made by nonprofit organizations and small business firms are used in a manner to promote free competition and enterprise without unduly encumbering future research and discovery; [and] to promote the commercialization and public availability of inventions made in the United States by United States industry and labor."

With this in mind, one would expect that success of these policies would be reflected in a surge of an ecosystem where industry and commercial entities increase their collaboration with universities. TTO's and TLO's were established to achieve these goals with the understanding that IP policies set by national law and university policies should serve this purpose.

Quantifying the success of such activities over the years is not simple as many of the influences on society are indirect in nature. However, some insight might be gained by considering the volume of such activities and their financial inputs. Most quantitative assessments are based on evaluation of patenting and startup activities of TTO/TLO's. This reflects a notion that has been sometimes erroneously developed over the years, that the main goal is technology commercialization for the financial benefit of the university, rather than the wider goal of technology transfer, as defined and discussed in chapters 3 and 4 in this report. The quantification of the technology commercialization is often presented in terms of the indices characterizing the commercialization pipeline, Figure 2.

The change in these indices over time is quite impressive [Weis et al 2018]. However, if values of commercialization income are presented in relative terms, as compared to total research income, the view derived is quite different: On the average, the relative values of commercialization income make up only a small portion of the research income, less than 5%. This value has been approximately the same over the last 20 years (Figure 22). At the same time, the research, supported by industry, has not been increasing and even shows some trend for decline, see Figure 22 and Figure 24.

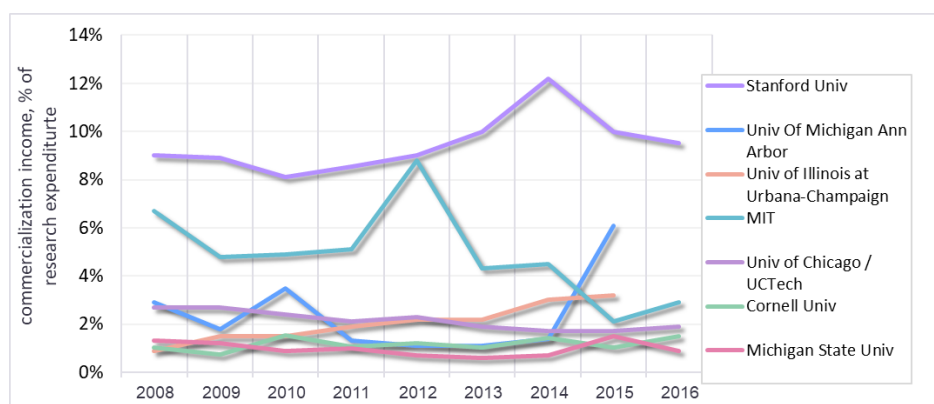
It should be noted that many governments developed policies and support programs for university-industry cooperation, such as consortia programs. Analysis of these has been quite favorable in terms of the cooperative results, such as the development of generic technologies. Case studies of university-business collaborations in Europe

indicated that success was usually associated with university acting closely with regional developments agencies, business, business groups, government organizations and even teaming up with other universities [Davey et al 2009]. Yet, the values in Figure 22 suggest that these successful models and case studies have not resulted in significant university-industry cooperation when the government is not involved. Some argue that this is the result of stringent IP policies of the universities, driven by the view of preference to supporting technology commercialization through TTO/TLO's. Such a view is not inconsistent with the trends seen in Figure 23, showing relative increase in industrial funding of research in the US up to about year 2000 and a decline thereafter. One may question whether this is associated with IP policies implemented in universities following the Bayh-Dole Act of 1980.

These trends imply that the policies implemented through TTO's/TLO's are, perhaps, not effective in reaching the overall goals set within the context of the third mission: the emphasis on commercialization is not yielding overall impressive results, while at the same time involvement of industry is almost at a standstill or slight decline, when considering the relative funding from industry supported research. It should be noted that increase in industry involvement in support of research is, sometimes, perceived with caution, as it might be at the expense of fundamental research and knowledge creation; yet there are indications that this is not necessarily the case, and even benefits to research output can be gained [Savage 2017].

Views of this kind, which are based on average values of indices, can be challenged, when considering the large disparity between universities, such as shown in Figure 9, Figure 10, Figure 12 and Figure 25. [Weis et al 2018] identified the top 25 universities based on the indices derived from the commercialization pipeline and demonstrated that all of them had consistent high values for all the indices in the pipeline. They suggested that these universities should be role models to make TTO/TLO's in universities more efficient. However, if the relative commercialization income of leading universities on this list is considered, it can be seen, that the values for these leaders are low, many of them below 5%, Figure 38.

Figure 38: Relative commercialization income of leading US universities, % of total research³³



³³ AUTM data

The trends outlined above are consistent with the analysis presented by [Valdivia 2013], Figure 13, which suggests that success is the result of blockbusters, and those are more likely to occur in universities with larger overall research income, which is characteristic to the list developed by [Weis et al 2018].

In evaluating these considerations, there is, perhaps, room to highlight a view that although the income from technology commercialization is relatively small, it provides the management of universities with un-assigned funds which can be more freely used for a variety of development needs. There is a scarcity in such resources, and even a small additional amount can make a difference. Yet, when arguments of this kind are to be considered, there is a need to take into account the net value of commercialization income, after deduction of expenses. These have been argued to be low or even negative, see section 8.1, [Merrill and Mazza 2011] [Valdivia 2013].

10. Concluding remarks

The spirit of the concluding remarks echoes quite well a statement made by Lita Nelson, the previous director of MIT TLO, in a recent interview [Nelson 2016]:

"It's already changing with an emphasis on entrepreneurship. The tech transfer offices have recognized that except for a few pharmaceuticals—and very few of those, that have been brought along by hospital funds to the point where the big pharma wants it—on the whole what comes out patented from university research is too risky and too early for knocking on the door of established companies."

"Any university that counts on its tech transfer to make a significant change in its finances is statistically going to be in trouble."

"So the universities have to start figuring out how do I ripen the technology to the point where it enters the big company stream of commerce."

Based on the findings, insights and discussions in this report, a need emerges for re-evaluating and re-visiting university policies with regards to its third mission. Such policies should be set to guide the activities of the TTO's and TTL's, which need to balance between technology commercialization, which is more linear in nature, and technology transfer with industry, which is more holistic, interactive and entrepreneurial in nature.

Goals should be set for the academia's contributions to the national economy and societal needs, and IP protection policies should be adjusted.

Greater emphasis on technology transfer and more intimate cooperation with industry may result in increase in research funding as well as in improved level and significance of research. More than that, such policies are more likely to be met by support of the academic faculty, and they should be an inherent part of the development of entrepreneurial activities in universities, which include education that is suitable to the needs of the industry and society as well as more significant and effective research.

It is recommended that the achievements of the universities regarding the third mission should be quantified and ranked on the national and international levels. They should be based on multiple indices to reflect various modes of achieving such goals, in view of the range of mechanisms of university-industry interactions, as seen, for example, in Figure 28.

Also, there is a need to consider, in the promotion of the academic staff, their achievements and contributions with regards to the third mission.

Nowadays, we are in the era of the 4th Industrial Revolution, which challenges the academia to enter and contribute to new areas in advanced research and advanced education in-order-to remain relevant during this revolution. The education syllabus and teaching methodologies should be modified and updated to meet the challenges and opportunities of this revolution. The research agenda should include these new areas of interest. But, more than that, the interactions between the academia, industry and society should be substantially more active, holistic and with entrepreneurship nature as recommended in this report. So, in the era of the 4th Industrial Revolution our recommendations should serve as a wake-up call for the academia.

This calls for comprehensive approach from all the stake holders, as outlined concisely below:

Academia

- Mechanisms: move from commercialization to transfer of technology
- Finances: move from royalties income to industrial research funding
- TTO/TLO: entrepreneurial approach of nurturing and intimate industrial relations
- IP policies: relaxing, with view of long term industrial support and donations

Industry

- IP policies: flexibility for publishing in return for IP rights
- Nature of research: support explorative research, not just exploitive/applied research

Government

- Policies: develop policies with long term objective of having sustainable ecosystem
- Incentives: set criteria for incentives to universities for achieving third mission goals, based on multiple indices

References

- [Allen and O'Shea 2014] The roadblock to commercialization, T. Allen, and R.O'Shea, The Financial Times, September 29, 2014
- [Alvarez Garcia 2015] Best University Practices and Tools in Entrepreneurship, Chapter 14, pp. 183-198 in Work and Study Habits in the Interconnected Age: What It Means for Businesses of the Future, M. Peris-ortiz, J.A. Gomez, F. Velez-Torres and C. Rueda-Armengot, Editors, Springer International, 2016
- [AUTM] Statistics Access for Tech Transfer Database (Association of University Technology Managers)
- [Bentur et al 2018] Education of engineers in the 21st century: Paradigms, insights and implications to Israel, A.Bentur, A.Zonnenshain, R.Naveh and T.Dayan, Samuel Neaman Institute Report, Technion, Israel Institute of Technology, November 2018
- [Bornmann 2013] What is societal impact of research and how can it be assessed? A literature survey, I.Bornmann, Journal of the American Society for Information Science and Technology, 64(2) 217-233, 2013
- [Bush 1945] Science: The Endless Frontier, A Report to The President, Office of Scientific and Research Development, V. Bush 1945, North Stratford: Ayer Co., 1995.
- [Cohen et al 2002] Links and Impacts: The Influence of Public Research on Industrial R&D, Cohen, W.M., R.R. Nelson, and J.P. Walsh, 2002, Management Science 48, 1–23.
- [D'Este et al 2007] University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? P. D'Este, P. Patel, Research Policy 36 (2007) 1295–1313
- [Davey et al 2009] 30 good practice case studies in University-Business Cooperation, T.Davey, T.Baaken, M.Deery, V.G.Muros, Editors, Report by the Science-to-Business Marketing Research Centre, Sponsored by the European Commission Directorate-General for Education and Culture, Public open tender EAC /37/2009: Study on the cooperation between Higher Education Institutions and public and private organisations in Europe, 2009
- [Donovan 2011] State of the art in assessing research impact: introduction to a special issue, C. Donovan, Research Evaluation, 20(3), pages 175–179, September 2011
- [Drucker and Goldstein 2007] Assessing the regional economic impacts of universities: A review of current approaches, J.Drucker and H.Goldstein, International Science Review, 30, 1, 20-46, January 2007
- [EC-OECD 2012] Guiding Framework for Entrepreneurial Universities, European Commission, EC-OECD, 1-54, 2012
- [Eesley and Miller 2018] Impact: Stanford University's Economic Impact via Innovation and Entrepreneurship, E.C. Eesley, and W.F. Miller, now Publishers, 2018

- [Etzkowitz and Leydesdorff 2000] The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations, H. Etzkowitz and L. Leydesdorff, *Research Policy* 29 , 109–123, 2000
- [European Commission 2009] Metrics for knowledge transfer from public research organizations in Europe, Report from the European Commission's Expert Group on Knowledge Transfer Metrics, The European Commission, 2009
- [European commission expert group 2011] A Composite Indicator for Knowledge Transfer Report from the European Commission's Expert Group on Knowledge Transfer Indicators, H. Finne, A. Day, A. Piccaluga, A. Spithoven, P. Walter and D. Wellen, The European Commission 2011
- [Feller et al 2002] Impacts of research universities on technological innovation in industry: evidence from engineering research centers, I. Feller, C.P. Ailes and J.D. Roesner, *Research Policy* 31, 457–474, 2002
- [Friedman and Silberman 2003] University technology transfer: do incentives, management, and location matter?, J. Friedman, and J. Silberman, *Journal of Technology Transfer*, 28, 81–85, 2003.
- [Gibb 2012] Exploring the synergistic potential in entrepreneurial university development: towards the building of a strategic framework. A. Gibb, *Annals of Innovation & Entrepreneurship*, 3, 2012
- [Graham 2014] Creating university-based entrepreneurial ecosystems: evidence from emerging world leaders, R. Graham, Massachusetts Institute of Technology, 2014
- [Grimpe and Hossinger 2016] Formal and informal knowledge and technology transfer from academia to industry: Complementarity effects and innovation performance, C. Grimpe and K. Hussinger, *Industry and Innovation*, 20(8), 683-700, 2016.
- [HEFCE 2016] Higher education innovation funding: Institutional five-year knowledge exchange strategies, Higher Education Funding Council for England, HEFCE, 2016
- [Hertzfeld et al 2006] Intellectual property protection mechanisms in research partnerships, H.R. Hertzfeld, A.N. Link, and N.S. Vonortas, *Research Policy*, 35, 6, 825-838, 2006.
- [Holi et al 2008] Metrics for the evaluation of knowledge transfer activities at universities, M.T. Holi, R. Wickramasinghe and M. van Leeuwen, Cambridge: Library House, 2008.
- [Huggett 2014] Reinventing tech transfer, B. Huggett, *Nature Biotechnology*, 32 (12), 2014
- [Kenny and Patton 2009] Reconsidering the Bayh-Dole Act and the current university invention ownership mode, M. Kenney and D. Patton, *Research Policy*, 38, 1407–1422, 2009

- [Lach and Schankerman 2004] Royalty sharing and technology licensing in universities, S. Lach, and M. Schankerman, *Journal of the European Economic Association*, 2, 252–264, 2004.
- [Link and Siegel 2005] Generating science-based growth: an econometric analysis of the impact of organizational incentives on university–industry technology transfer, A.N. Link and D. S. Siegel, *European Journal of Finance*, 11, 169–182, 2005.
- [Link et al 2007] An empirical analysis of the propensity of academics to engage in informal university technology transfer, A.N. Link, D.S. Siegel and B. Bozeman, *Industrial and Corporate Change*, 16(4) 641–655, 2007
- [Love 2014] Do University Patents Pay Off? Evidence from a survey of university inventors in computer science and electrical engineering, B.J. Love, *Yale Journal of Law and Technology*, 16(2), *Yale Journal of Law and Technology Article 2*, 285-343, 2014
- [Mansfeld 1991] Academic research and industrial innovations, E. Mansfeld, *Research Policy* 20, 1-12, 1991
- [Mansfeld 1998] Academic research and industrial innovation: An update of empirical findings, *Research Policy*, 26, 773-776, 1998
- [Markman et al 2004] Entrepreneurship from the Ivory Tower: Do Incentive Systems Matter? G.D. Markman, P.T. Gianiodis, P.H. Phan and D.B. Balkin, *Journal of Technology Transfer*, 29, 353–364, 2004
- [Markman et al 2008] Full-time faculty or part-time entrepreneurs, G.D. Markman, P.T. Gianiodis, and P.H. Phan, *IEEE Transactions on Engineering Management*, 55(1), 29-36, February 2008
- [Merrill and Mazza 2011] Managing university intellectual property for the public interest, S.A. Merrill and M.A.Mazza, editor, *The National Research Council, The National Academy Press, Washington*, 2011
- [Miller 2005] Repairing the Bayh-Dole act: A proposal for restoring non-profit access to university science, A.Miller, *Boston College Intellectual Property & Technology Forum*, <http://www.bciptf.org>, 2005
- [Munari and Toschi 2019] The intersection between capacity building and finance, F. Munari and L.Toschi, pp. 105-121 in *Capacity Building in Technology Transfer: The European Experience*, M.Granieri and A.Basso, editors, Springer International Publishing, 2019
- [Ndou et al 2018] Insights for shaping entrepreneurial education: Evidence form European entrepreneurship centers, V.Ndou, G.Secundo, G.Schiuma and G.Passiante, *Sustainability*, 10, 4323, 2018
- [Nelson 2016] Exit Interview: Lita Nelsen on MIT Tech Transfer, *Startups & Culture*, Interview by Jeff Engell, Xconomy, May 31, 2016 (website)
- [OECD 2016] *OECD Science, Technology and Industry Outlook 2016*, OECD Publishing, Paris, accessible on library or browse the full book online. Data extracted on 17 Dec 2018 from OECD.Stat

- [O'Shea et al 2007] Delineating the anatomy of an entrepreneurial university: the Massachusetts Institute of Technology experience, R.P. O'Shea, T.J. Allen, K.P. Morse, C. O'Gorman, and F. Roche, *R&D Management*, 37(1), 1-16, 2007
- [Ouchi 2011] An Ecosystem for entrepreneurship at UCLA: Part I – An invitation for campus wide input (2011), Part II – Transition to new technology transfer process (2011), Part III - A strategic blueprint for entrepreneurship at UCLA W.G. Ouchi, UCLA, 2014
- [Petit 2004] Why do we need fundamental research?, J.C.Petit, *European Review*, 12(2), 191–207, 2004
- [Reslinski and Wu 2018] The value of royalty, M.A. Reslinski and S.B Wu, 6pp, *Nature Biotechnology*, Advanced Online Publication, 2018
- [Roberts and Eesley 2011] Roberts, E. B., & Eesley, C. E. (2011). Entrepreneurial impact: The role of MIT. *Foundations and Trends in Entrepreneurship*, 7(1–2), 1-149, 2011
- [Rosenberg 1994] N. Exploring the Black Box: Technology, Economics, and History, N. Rosenberg, New York, Cambridge University Press, 1994
- [Roessner et al 2013] The economic impact of licensed commercialized inventions originating in university research, D.Roessner, J.Bond, S.Okubo and M.Planting, *Research Policy*, 42, 23-34, 2013
- [Salter and Martin 2001] The economic benefits of publicly funded basic research: A critical review, A.J.Salter and B.Martin, *Research Policy* 30 (3) 509-532, 2001
- [Sampat 2006] Patenting and US academic research in the 20th century: The world before and after Bayh-Dole, N.B. Sampat, *Research Policy* 35, 772–789, 2006
- [Savage 2017] Industry links boost research output, N. Savage, *Nature Index*, S11-S13, 2017
- [Schaeffer et al 2018] The complementarities between formal and informal channels of university–industry knowledge transfer: a longitudinal approach, V. Scaheffer, S. Ocalan-Ozel and J. Penin, *The Journal of Technology Transfer*, July 2018
- [Siegal et al 2004] Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies, D.S. Siegel, D.A. Waldman, L.E. Atwater and A. N. Link *Journal of Engineering and Technology Management*, 21, 115–142, 2004.
- [Stoles 1997] Pasteur's Quadrant, Basic Science and Technology Innovation, D.E.Stokes, Brookings Institution Press, Washington D.C., 1997
- [Takata et al 2018] Nursing entrepreneurship: A conceptual study of a new focus for technology transfer professionals, M. Takata, K. Nakagawa, M. Yoshida, T. Matsuyuki, T. Matsuhashi and K. Kato, *The ISPIM Innovation Conference – Innovation, The Name of The Game*, Stockholm, Sweden on 17-20 June 2018
- [Thursby and Thursby 2007] University licensing, J.G.Thursby and M.C.Thursby, *Oxford Review of Economic Policy*, 23 (4) 2007, 620-639, Paper presented at

The ISPIM Innovation Conference – Innovation, The Name of The Game, Stockholm, Sweden on 17-20 June 2018.

- [Tijssen et al 2016] University–industry R&D linkage metrics: validity and applicability in world university rankings, R.J. Tijssen, A. Yegros-Yegros and J.J. Winnink, *Scientometrics*, 109:677–696, 2016
- [Tseng and Raudensky 2014] Performance evaluations of technology transfer offices of major US research universities, A.A. Tseng and M. Raudensky, *J. Technol. Manag. Innov.* 9(1), 93- 102, 2014
- [US Department of Commerce 2013] *The Innovative and Entrepreneurial University: Higher Education, Innovation & Entrepreneurship in Focus*, U.S. Department of Commerce, October 2013
- [Valdivia 2013] *University Startups: Critical for improving technology transfer*, W.D. Valdivia, Center for Technology Innovation at Brookings, November 2013
- [Valentin and Jensen 2007] Effects on academia-industry collaboration of extending university property rights, F. Valentin, R.L. Jensen, *J. Technology Transfer* 32, 251–276, 2007
- [WEF 2016] *The future of jobs: employment, skills and workforce strategy for the Fourth Industrial Revolution*, World Economic Forum, 2016
- [Weis et al 2018] Evaluating disparities in the U.S. technology transfer ecosystem to improve bench to business translation, J. Weis, A. Bashyam, G.J. Ekchian, K. Paisner and N.L. Vanderford , *F1000Research* 2018, 7:329 Last updated: 08 May 2018
- [Yoon and Lee 2013] Entrepreneurship education and research commercialization of engineering-oriented universities: an assessment and monitoring of recent development in Korea, H.Y. Yoon and J.J. Lee, *International Journal of Engineering Education*, 29(5), 1068-1079, 2013
- [Zomer and Benneworth 2011] *The rise of the university's Third Mission*, A.Zomer, and P. Benneworth, in J. Enders, H. F. de Boer & D. Westerheijden (eds) *Reform of higher education in Europe*, Rotterdam, Sense Publishers, 2011

Appendix A

Conflict of Interest Policies at MIT - Summary

A number of basic principles guide the conflict of interest policies for tech transfer – strict policies on managing it:

- Entrepreneurial activities and tech transfer are by-products (not purpose) of academic mission of education, basic research and dissemination of knowledge
- Tech transfer activities must not deflect or distort this core mission
- No incubation of the company within MIT. Once it has been formed- faculty may consult, be board members, but not line officers
- MIT may take risks by taking equity in partial lieu of royalties
- Faculty are required to report all outside consulting activities with startups
- Faculty may not negotiate terms of licensing with MIT
- No sponsored research will be accepted from the company if the faculty founder holds equity in the start up
- No commerciality of MIT research results is permitted
- Before starting a company, a faculty must sign a "conflict of avoidance statement": Promise not to accept research support from company, not to suppress for the company benefit the dissemination of research results developed at MIT, not to use students on any company project
- Financial dealing between the new company and MIT are kept at arm's length. MIT will not invest in early founding rounds and take no board seat. MIT treasurer, not TLO, manages equity received by the Institute
- MIT provides exclusive licenses to academic entrepreneurs
- Royalty distribution: once patent costs are paid, and 15% royalties are paid to TLO, 1/3 of the remaining to investor, and the rest divided between departments interdisciplinary centers and MIT General Fund

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Samuel Neaman Institute
for National Policy Research

Tel. 972-4-8292329 | Fax. 97-4-8231889
Technion City, Haifa 3200003, Israel
www.neaman.org.il