A Quantitative Single-Site Study of Technology Transfer Procedures and Outcomes

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ABSTRACT

This study aims to provide a quantitative analysis of a significant shift in those practices within a single institution and across a five-year period of time. The analysis indicates that there was a positive change in outcomes, with a corresponding increase in worker output. Licenses, including those initiating new companies, increased. Sustainability and wider economic impacts are discussed.

KEY WORDS

Technology transfer, university research, economic growth, impact, start-up, spin-out, innovation, commercialization

INTRODUCTION

1. Introduction

Technology transfer in the academic research setting enables the connection of industrially-useful developments with the wider community, yielding economic and social benefits, and allowing use of a technology that was pioneered or invented from within that academic research setting.

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The Bayh-Dole Act was signed into law on December 12, 1980, and is credited with beginning a new era in the field of technology transfer. The Act encouraged the recognition, availability, and uptake of useful inventions created through the use of federal funding. The Act established incentives for research-intensive universities to engage with commercial organizations both large and small to facilitate the useful transfer of potentially valuable technologies.

The Act may have simplified the process, instigated a uniform patent policy, and potentially eased restrictions on licensing (while notably creating administrative burdens in some areas). Perhaps most importantly, it encouraged universities to assert ownership of their inventions, and to seek patent applications (Siegel, Waldman, and Link, 2003). It was hoped that the Act would ultimately accelerate commercialization of university technologies, but perhaps its greatest contribution was to facilitate the establishment of a national framework for the handling of certain valuable technologies arising from university research. That framework has led to a vibrant technology transfer community within the United States, which has subsequently been imitated around the world.

After the Bayh–Dole Act passed, university patent applications and granted patents increased substantially, with a more than six-fold increase in patents granted annually to universities between 1980 and 1996, and annual revenue streams increasing more than three-fold between 1990 and 1997 (GAO, 1998).

Over time certain trends in university technology transfer have occurred (Bercovitz, Feldman, Feller, and Burton, 2001), including universities making efforts to open or expand their technology transfer offices (Feller, 1990), changes in the types of patents being filed (Eisenberg, 1996), licenses and licensing income, and temporal changes in the quantity and quality of academic patents (Mowery and Ziedonis, 1999).

While some universities may use outside services, the academically-based technology transfer office is the most common conduit that allows new technologies and discoveries resulting from university research to move, on a practical basis, into commercial organizations both large and small (Geroski, 2000).

2. Technology transfer within universities

Universities are often very different from one another, imbued with unique history and character. These factors, combined with the resources a university may possess, and with the available funding sources and market forces, may be some of the reasons for the differing organizational structures within universities, including the technology transfer office organization, policies, procedures, and their outcomes (Bercovitz, Feldman, Feller, and Burton, 2001).

Technology transfer, knowledge transfer, and knowledge exchange, are terms often used within the broad field of technology transfer. Universities may aspire to a spectrum of knowledge exchange, but within a technology transfer office, there are more specific forms of commercial agreement being transacted.

The interactions between universities and commercial entities (particularly large corporations) has been described as a two-way flow of knowledge (including skills and know-how) between collaborating partners (Guerrero, Cunningham, and Urbano, 2015). These interactions certainly occur, but within the United States, a technology transfer office typically offers providing commercial access to property and rights-controlled assets in exchange for the commercial party not being sued for rights infringement. The assets of value are identified (such as by a patent application number), the collateral is typically financial, and the instrument to formalize the exchange is a license document.

There is considerable literature analyzing the relationship between a technology transfer office's inputs (such as resources, organizational structure, reporting hierarchies, and incentives) and outputs (such as patents, licenses, and revenues generated) (Bercovitz, Feldman, Feller, and Burton, 2001), and it has been suggested that the efficiency of technology transfer offices may vary between universities (Siegel, Waldman, and Link, 1999).

Developments like inventions are protected by drafting and filing a patent application, thereafter initiating a process of often-unseen but important steps towards ensuring the chain of custody of the invention. Such steps include scrutinizing inventorship, and identifying and contacting any third-party institutions that may be joint inventors. Sources of funding and contributions (such as provision of proprietary materials) are investigated, and the necessary activities (such as administrative agreements) are undertaken. Once a patent application has been filed, and ownership issues assessed, the technology transfer office can make the patent available to the business community. Methods of making the patent available can include marketing, including online listings, bulletins, and news pieces. Universities with more sophisticated technology transfer functions may have greater outputs or efficiency than comparable but less-skilled universities (Siegel, Waldman, and Link, 1999). An interested party will communicate their commercial interest in the patent, and a business manager or licensing officer will typically engage with the interested party.

Licensing is commonplace within technology transfer, and universities typically either insist on the use of their in-house templates, or alternatively the university is willing to negotiate around externally-drafted documents. Within the area of template licenses, those of the Regents of the University of California are likely to be amongst the most recognizable licensing instruments around the world. Templates include those designed to provide access to patent rights, copyrights in documents or software, novel materials, and combinations thereof. Collectively these could be referred to as technology licenses.

3. Reforming technology transfer practices

Traditional or 'linear models' for technology transfer may be less useful or even out of date for the modern academic-commercial environment. A 'one-size-fits-all approach' may not meet the needs of potential participants, and it has been suggested that universities be entrepreneurial, and even dynamic, in their approach to technology transfer (Bradley, Hayter, and Link, 2013). Universities are often slow to change their fundamental practices, but universities have undertaken measures in an attempt to improve outcomes from their technology transfer offices. The University of North Carolina was an early university to introduce an 'express license' (University of North Carolina, 2019). Such measures represent efforts to improve outcomes in the technology transfer process. It is important to note that these efforts are typically undertaken one at a time. In doing so, the university can assess the outcomes, while reducing risks of unforeseen consequences. If a program is not successful, it can be halted or amended. In some cases, a university can undertake a sophisticated long-term program of initiatives to grow and expand the innovation ecosystem (Huang-Saad, Fay, and Sheridan, 2017).

Commercial entities may believe that universities are excessively seeking profit from a technology on offer (Siegel, Waldman, and Link, 2003). This may have some validity when considering that a new and complex technology, with limited data supporting it, may be a lengthy commercial development opportunity, especially when adjusting for the internal and external risks inherent with such an activity. The rational person might be better off putting their money in a bank. Some may argue that an effect of the Bayh-Dole Act is that they do not.

Universities have numerous inputs, including undergraduate and graduate students, staff, and funding, and outputs that include rates of graduation, journal publications, and local and regional services. Funding to universities can arise from sources that include regions, states, non-profits, industry, and the federal government. It has been suggested that the outputs of technology transfer offices (including disclosures processed, and licensing activity), may be influenced by organizational inputs (such as resources, reporting structures, autonomy, and incentives). There is also evidence suggesting that modulation of inputs may lead to changes in outputs (Bercovitz, Feldman, Feller, and Burton, 2001), but studies rightly note that there are limitations on sample sizes within many studies.

The most critical inputs within organizational factors have been suggested to be faculty and tenure reward systems, the staffing and compensation practices within a technology transfer office, and breaking down barriers between universities and commercial entities. At high levels, managers, entrepreneurs, and scientists, all report that university bureaucracy and inflexibility may be barriers to effective and efficient technology transfer. There is evidence that involvement in technology transfer activities is not given sufficient motivation to faculty and researchers to warrant their involvement, with 60% of administrators and 70% of scientists reporting this as a problem (Siegel, Waldman, and Link, 2003).

It has been suggested that there is a correlation between university outputs and the formation of new start-up companies, suggesting that universities can positively impact regional economic development (Calcagnini, Favaretto, Giombini, Perugini, and Rombaldoni, 2016). Indeed, university-derived start-up companies may serve an important role in society by moving researchderived new technologies into the wider economic sphere, in a process that may not otherwise happen (Fini, Rasmussen, Siegel, and Wiklund, 2018; and Fontes, 2005).

4. Defining the university environment under study

The University of California San Diego ("UC San Diego") is a public land grant university located in southern California, and is one of ten main campuses of the University of California, which is one of the world's largest public university systems. UC San Diego was established in 1960, and by the second decade of the 21st century it was recognized as a research-intensive institution with sophisticated operations such as a National Cancer Institute ("NCI") and the San Diego Supercomputer Center ("SDSC"). As a research-intensive institution, UC San Diego had grown its research budget to an annual sum in the region of one billion Dollars (between FY2013* and FY2015 the mean annual research budget was $1.029 Billion Dollars. *Please see below for the definition of fiscal year). The Technology Transfer Office ("TTO") at UC San Diego was established in April 1995, and by April of 2015 the TTO had cumulatively generated at least: 6,174 innovations disclosed, 3,600 U.S. patent applications, 1,090 U.S. patents issued, 1,070 licenses granted, 204 UC San Diego technology start-ups, and $334 million of income (Canlen, 2015). UC San Diego TTO was a sophisticated technology transfer operation, using advanced practices, such as an 'Express' licensing model (Mueller, 2012).

Reorganization of practices and procedures

In FY2016 UC San Diego began a process of reorganizing the operations of the TTO, with the intention to 'break down barriers to commercialization' and to increase the output of the TTO and of the university. This program of reducing 'friction' (hence 'Frictionless') around getting

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technologies into the hands of commercially-interested parties began with renaming the TTO to the Office of Innovation and Commercialization ("OIC").

Cornell Tech very successfully introduced the 'Runway program' that formalized entrepreneurship training, enhanced technology transfer functionality, and resulted in building sustainable companies, integrated functionalities within the university, and offered additional career options (de Haan, Shwartz, and Gómez-Baquero, 2020).

There are studies (Athey and Stern, 1998; Ichniowski, Shaw, and Prennushi, 1997) that suggest the importance of clusters of complementary organizational practices that may modulate technology transfer outputs. The Frictionless program operated within this conceptual framework, with multiple changes to inputs potentially benefiting from 'interaction effects' to encourage increased outputs. It is rare that experimental changes of this magnitude are undertaken at a large and sophisticated university environment.

There was a broad concept of what changes could be considered for implementing the Frictionless program within the new technology transfer office structure of OIC, provided that the university's missions of education, research, and publication were unimpeded, and provided that any changes met with state and federal laws. Accordingly, a range of changes were gradually implemented and refined between FY2016 and the end of FY2019.

The transition from TTO to OIC began with setting a goal of doubling the number of licenses and doubling the number of start-up companies arising out of the work of the office. Such an ambitious goal was recognized as difficult, even unlikely to be achieved, given the size and complexity of the research operation at UC San Diego, but such a goal was recognized as being a necessary reference point for the amendment of inputs (such as operational changes). In support of this goal, one key objective was to demonstrate that OIC was engaged with the research and commercial communities, and 'open for business'.

It has been noted that there should be greater efforts towards establishing a 'mutual understanding' amongst universities and commercial entities (Siegel, Waldman, and Link, 2003). During the creation of the 'Frictionless' program, there were considerable efforts at outreach, including stakeholder meetings, innovation councils, town halls, and listening sessions. Over time, the feedback gathered at these sessions formed a substantial parts of the alterations to the inputs to technology transfer that embody the Frictionless program. Meetings, seminars, and presentations were held, and the local business community was consulted on potential changes, and their feedback implemented where possible.

The local innovation community around a university is an important element in developing entrepreneurial outcomes, and it was recognized that the Frictionless program should recognize and engage experienced 'Innovators', particularly within the senior faculty community. Such peers could offer guidance to those people interested in commercializing UC San Diego technologies, including post-doctoral researchers.

Technology transfer offices often aim to conclude commercial licenses with established companies. Established companies, often classified as 'large entities', are a cornerstone of technology transfer licensing practices. Large companies are aware of technology transfer offices, and often engaged with them, but such established companies are a largely-fixed parameter for outputs, and are an unlikely target for increased licensing interest. As part of the goals of the Frictionless program, new potential licensing customers were identified as being a necessary and desirable parameter. Therefore, newly-formed small companies were identified as an opportunity for increased licensing activity. New companies need a founder, and there are indications that a focus on faculty-initiated start-ups may be less effective than focusing on recently graduated students as future founders (Astebro, Bazzazian, and Braguinsky, 2012). For start-up companies to be a new potential licensing customer group, founders would be required, and one key community was identified: doctoral and post-doctoral candidates.

In keeping with the primary missions of the university of teaching and research, doctoral qualification would not be impeded, but if a recently-graduated doctoral candidate or post-doctoral researcher wished to start a new company, especially around a new technology they had invented or created, they would be encouraged.

In FY2017, OIC introduced the 'Accelerating Innovations to Market' ("AIM") funding program, with the intention to provide support to advance UC San Diego technologies towards commercial impact. Awards of up to $50,000 would be made available to selected applicants, and selection parameters included stage of development, goals, patent status, and future commercial plans. It should be noted that AIM funding was not present during either FY2015 or FY2020. The correlation, if any, between AIM funding and new company formation will be covered in a separate study.

Licenses are a key outcome for any technology transfer office. As a member of the University of California, UC San Diego uses the 'the Regents of the University of California' license templates, which are amongst the most recognizable licensing documents in the world. As part of the Frictionless program, license templates, and licensing parameters, were adjusted to remove out-of-date and little-used terms, and also reduce complexity and overall length. While the fundamental framework of the license template was not altered, exclusive patent license documents (a key output of the technology transfer office) were shortened by removing outdated or redundant language. New licensing templates were introduced for therapeutics start-up

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companies, non-therapeutic start-up companies, and start-up companies based around software. These licenses would typically be exclusive in nature, as is standard practice in the field for start-up companies. Non-exclusive license templates to copyrights (including software), patent rights, and materials (at UC San Diego called 'Bailment Licenses') documents remained largely unchanged within the Frictionless program. How these licensed were handled did change, with goals for reduced time to completion, and reducing processing burdens. Alongside changing the physical license outputs of OIC, the Frictionless program also changed the processes used within the office. Time-to-completion was desired to be reduced, and there was a goal to increase output per licensing officer (renamed to 'Innovation and Commercialization Managers' or 'ICM's').

Alongside licenses, technology transfer offices need to handle a range of other functions, including agreements that facilitate the conduct of research (such as agreements covering confidentiality, material transfer, and the management of jointly-owned technologies). These agreements, and the processes covering them, were unchanged.

One burden within a technology transfer office is processing invention disclosures into provisional patent applications, and the subsequent stewardship of those patent-pending technologies. In recognition that burdens such as licensing would be increased, a goal was set to be more rigorous in patent applications as part of the Frictionless program. In effect, the quality of patent applications was desired to increase, through the rigorous application of questions around commercial potential, competitive landscape, and market feedback. Efforts were to be focused more on those technologies that seemed most capable of commercialization, and 'commercialization review panels' were implemented for technologies where the commercial business case for a technology was uncertain.

Technology transfer offices can be seen as a source of revenue for a university. Income brought in to the office may need to be shared with inventors and their departments, but a portion of the income may be available to the wider institution as restricted or even unrestricted funding. As part of the Frictionless program, UC San Diego recognized that income from technology transfer operations were relatively small in comparison with a research budget of a billion Dollars or more each year. It was also noted that a license can take many years before producing substantial income, and the likelihood of any individual license generating substantial sums is low. A logical conclusion for the Frictionless program was to complete as many licenses as reasonably feasible, and allow market forces to proceed. Additionally, for therapeutic candidates, and for technologies more broadly, the risks of failure of any given project undertaken can be high. In summary, it was concluded that when adjusting for risk, and given the potential time taken to achieve commercial outcomes, the risk-adjusted net present value of start-up licenses could be recognized as being low. This justified back-loading the value proposition under a start-up license. In simple terms, the upfront costs of taking an exclusive license to start a new company were reduced to a minimum.

This study aims to perform an analysis of the last fiscal year of outcomes before the program was started, and make a comparison to the first fiscal year where substantially all changes within the program had been implemented.

5. Hypotheses

Accordingly, for this study a number of hypotheses have been developed, based on what a reasonable observer might have reasonably conjectured before the Frictionless program was

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introduced. Many large organizations attempt to implement programs of substantial change, often without significant success. Accordingly, the first hypothesis is:

Hypothesis 1 (H1). *Implementing a program of changes regarding the handling of technologies by the technology transfer office will result in no substantial change in outputs.*

Developing technologies takes time, patenting is a lengthy process, and building relationships with academic researchers is lengthy to develop and easily damaged. Also, companies and investors are used to normal ways of doing business, and changes may be unfamiliar and worthy of concern. Therefore, for this study:

Hypothesis 2 (H2). *Attempting to implement a dramatic program of changes within the technology transfer office will induce a substantial decrease in measured outputs.*

Examining efforts at other institutions, or previous efforts within UC San Diego (such as the Express License), it could be expected that impacts from the changes could yield negligible substantial impact. Additionally, technology transfer is dependent on research activities as providing the 'raw material' to produce commercial transactions. Therefore:

Hypothesis 3 (H3). *If the implementation of a dramatic program of changes within the technology transfer office induces any increase in measured outputs, such increase will not be substantial, or at best only in line with any change in research funding.*

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Achieving outputs in technology transfer is recognized to potentially need a combination of inputs, and if incentives are focused in a limited fashion, then any change in the outputs may be limited to those being incentivized (Bercovitz, Feldman, Feller, and Burton, 2001). Accordingly, it may be stated that, through the implementation of a dramatic program of changes within the technology transfer office, the differential burden of different forms of commercial transactions can be measured, and any increase in outputs might be concentrated on the 'easiest' commercial transactions. Therefore:

Hypothesis 4 (H4). *If there are increases in measured outputs, such increase will be skewed towards the easiest transactions.*

It has been widely suggested that university research activities can have impacts on the wider economic area, including that there may be a direct relationship between the research activities of a university and the number of start-up companies in the area (Barnia, Eberts, and Fogarty, 1993). Both formal (Zucker, Darby, and Brewer, 1998) and informal (Audretsch and Stephan, 1996) linkages are present within their shared area between university-based scientists and large and small businesses. There may be geographic localization of research outputs, with local or regional businesses more likely to cite locally-generated patents in their own patent filings (Jaffe, Trajtenberg, and Henderson, 1993). If the Frictionless program did produce tangible changes to technology transfer office outputs, it may be postulated that such changes in university outputs might to some degree be reflected in outputs externally, in the local area. Therefore:

Hypothesis 5 (H5). *If H3 and H4 are disproven, and there are increases in measured outputs, there may be corresponding impacts to the local and regional economy.*

6. Methods and analysis

The University of California operates a fiscal year (FY) of July 1st through June 30th. For the purposes of this study the years of analysis will be FY2015 (ending June 30th of calendar year 2015), and FY2020 (ending June 30th of calendar year 2020). Any reference to external data that uses calendar year will be referred to as 'calendar year'. For this study FY2015 represents the last fiscal year before changes were made to the operations of the original TTO, with all the substantial changes implemented before completion of FY2019.

The data used in this study are internal OIC data. These data have been aggregated to preserve confidentiality.

Internal classifications of 'a license' were consistent throughout the study. A start-up company was classified as a new (formed within the last two years) business (incorporated as a profit-seeking LLC or C-Corporation) that took a license to a UC San Diego technology as a foundational element of its starting business plan.

Association of University Technology Managers ("AUTM") conducts an annual survey into licensing and new company activity by technology transfer offices. The University of California Office of the President ("UCOP") conducts an annual survey of new company formation. In the case of both AUTM and UCOP surveys, the methodology may differ slightly from internal categorizations within OIC. For the purposes of this study, to ensure consistency between the year's data being studied, internal classifications of licenses and new companies have been used.

Given the complexity of this area, there is a need for additional data from many universities, including in-depth single site case studies, so that there can be wider study of the impacts of organizational factors and its connection to technology transfer outcomes, including the efficiency of technology transfer activities (Bercovitz, Feldman, Feller, and Burton, 2001).

It has been postulated that relative performance of the outputs of a technology transfer office may have dependency on factors that include organizational practices, such as the university's management of intellectual property practices and procedures (Siegel, Waldman, and Link, 2003), but data has been highlighted as lacking. Face-to-face interviews are useful, but quantitative data on changes to inputs and the resulting outputs is difficult to obtain.

Leading universities that have substantial research income, notable production of patent applications and grants, and sophisticated procedures for conducting licensing transactions may be considered 'best practice' institutions (Bercovitz, Feldman, Feller, and Burton, 2001), but that raises the question: what if one best-practice institution were to dramatically changes its inputs in a short space of time? This study hopes to provide some quantitative analysis of that question.

7. Results and discussions

Research funding, reported inventions, patent applications, office staffing, and administration

While research funding had been steady for a number of years up to FY2015, annual research funding increased by around thirty percent between FY2015 and FY2020. The number of total disclosures made to OIC increased by around a third between FY2015 and FY2020, with Inventions disclosed increasing by more than a third, Copyright or Trademark disclosures increasing by eighty percent. The disclosure of materials arising from research activity only increased by twenty percent. In contrast, patent applications filed did not substantially change between FY2015 and FY2020 (Table 1).

Table 1. Research Funding, Inventions and Disclosures.

	FY2015	FY2020	Percent (%) Change
Total UC San Diego research funding	$1,012,200,000	$1,341,100,000	32.5%
Inventions disclosed	234	323	38.0%
Copyright or Trademark disclosed	26	47	80.8%
Materials disclosed	109	131	20.2%
Total Disclosures Reported	369	501	35.8%
Provisional Patent Applications filed	209	210	0.5%

Licensing staffing and experience

Licensing Officers, or ICMs within OIC, manage the direct interactions with researchers, inventors, and external commercial parties. In FY2015 there were nine Full-time equivalents ("FTE") in the ICM role, and seven ICM FTEs in FY2020, and decline of twenty percent. The total years of licensing experience for the team fell in aggregate from 93.5 in FY2015 to 69.0 in FY2020, a decrease of a quarter, but the median experience of each ICM did not change (Table 2).

Table 2. Licensing staff number and experience.

	FY2015	FY2020	Percent (%) Change
Number of Licensing Officers / ICMs	9	7	-22.2%
Total years of licensing experience	93.5	69.0	-26.2%
Mean experience per Licensing Officer / ICM	10.4	9.9	-5.1%
Median experience per Licensing Officer / ICM	10.0	10.0	0%

Administrative agreements

Agreements, licensing data, and start-up companies. Basic administrative agreements completed by OIC fell from 18 in FY2015 to 8 in FY2020, a decrease of about half (Table 3).

Table 3. Administrative Agreements.

	FY2015	FY2020	Percent (%) Change
Copyright administrative agreements (including inter-institutional agreements)	8	1	-87.5%
Inter-office memoranda of understanding	8	5	-37.5%
Non-copyright Administrative agreements	2	1	-50.0%
Royalty sharing with non-profit sponsors	0	1	100%
Total	18	8	-55.6%

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Agreements facilitating the conduct of research

Agreements facilitating the conduct of research declined slightly, with the total number of agreements declining by around ten percent between FY2015 and FY2020, largely due to a decrease in Material Transfer Agreements without Reimbursement (Table 4).

Table 4. Agreements facilitating the conduct of research.

	FY2015	FY2020	Percent (%) Change
Copyright License to an academic end user, and Copyright Material Transfer Agreement	11	10	-9.1%
Unfunded Collaboration and Material Transfer Agreement	2	4	100%
Material Transfer Agreement without Reimbursement	237	208	-12.2%
Inter-Institutional Agreement with a Non-UC university	5	9	80.0%
Inter-Institutional with a UC campus	12	11	-8.3%
Total	267	242	-9.4%

Licensing

Agreements facilitating the conduct of research declined slightly, with the total number of agreements declining by around ten percent between FY2015 and FY2020, largely due to a decrease in Material Transfer Agreements without Reimbursement (Table 5).

Table 5. Commercial licenses.

	FY2015	FY2020	Percent (%) Change
Letter Agreements	31	14	-54.8%
Copyright licenses, non-exclusive	21	61	190.5%
Copyright licenses, exclusive	4	4	0%
Patent/material licenses, non-exclusive	19	50	163%
Patent/material licenses, exclusive	30	50	66.7%
Total	105	179	70.5%
Start-up companies	15	23	53.3%

Analysis of office output per licensing professional

Output of licenses and start-up companies per ICM increased substantially after the introduction of the Frictionless program. Letter agreements reduced, but non-exclusive copyright licenses, non-exclusive patent and material licenses, and exclusive patent/material licenses, all increased. Broadly, output was doubled, but it is worth noting that non-exclusive copyright licenses and non-exclusive patent and material licenses demonstrated the most sizable increases (Table 6).

Table 6. Office output, based on licenses per ICM.

	FY2015	FY2020	Percent (%) Change
Letter agreements	3.44	2.00	-41.9%
Copyright licenses, non-exclusive	2.33	8.71	273.5%
Copyright licenses, exclusive	0.44	0.57	28.6%
Patent/material licenses, non-exclusive	2.11	7.14	238.3%

Patent/material licenses, exclusive	3.33	7.14	114.3%
Total commercial licenses	11.67	25.57	119.2%
Start-up companies	1.67	3.29	97.1%

Time to deal completion

Licenses take different amounts of time to reach completion. Copyright licenses tend to be short, and quicker to execute. Licenses that contribute to the formation of a new company are amongst the longest agreements to reach execution. Patent and material licenses, exclusive and non-exclusive, fall in-between. Data in Table 7 shows the cumulative FY volume of office output, using the median deal time for all deals measured. Whether the Frictionless program contributed to any changes in average deal times is a more complex question and will be part of a separate study.

Table 7. Office output, based on per days of deal-time for different types of licenses.

	Deal time (days, median)	FY2015	FY2020	Percent (%) Change
Copyright licenses, non-exclusive	21	441	1281	190.5%
Patent/material licenses, exclusive/non-exclusive	50	2450	5000	104%
Start-up companies	97	1455	2231	53.3%

Output per licensing professional

From these data, there are indications that the Frictionless program increased staff output.

Table 8. Output by measurement of units of deal time per staff member.

	FY2015	FY2020	Percent (%) Change
Copyright licenses, non-exclusive	49.0	183.0	273.5%
Patent/material licenses, exclusive/non-exclusive	272.20	714.3	162.4%
Start-up companies	161.7	318.7	97.1%

Outputs per unit of research funding

During the period of study, research funding increased by nearly a third. Corresponding invention disclosures remained largely unchanged. The reports of new materials were largely unchanged, but the number of provisional patents filed decreased by 24%. Letter Agreements dropped by nearly two-thirds, but non-exclusive copyrights licenses increased substantially. Non-exclusive patent and materials licenses nearly doubled in the period of study, and exclusive patent and materials licenses increased by 25%. New companies formed via licensing increased by 15% per unit of research funding (Table 8).

Table 8. Outputs per $100 million of research funding.

	FY2015	FY2020	Percent (%) Change
Total UC San Diego research funding	$1,012,200,000	$1,341,100,000	32.5
Inventions disclosed	23.118	24.085	4.2
Copyright or Trademark disclosed	2.569	3.505	36.4
Materials disclosed	10.769	9.768	-9.3
Total Disclosures Reported	36.455	37.357	2.5
Provisional Patent Applications filed	20.648	15.659	-24.2
Letter Agreements	3.063	1.044	-65.9

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Copyright licenses, non-exclusive	2.075	4.549	119.2
Copyright licenses, exclusive	0.395	0.298	-24.5
Patent/material licenses, non-exclusive	1.877	3.728	98.6
Patent/material licenses, exclusive	2.964	3.728	25.8
Total	10.373	13.347	28.7
Start-up companies	1.482	1.715	15.7

8. CONCLUSIONS

Following the introduction of the Frictionless program at UC San Diego, it is possible to draw some conclusions from the outputs of the OIC activities in comparison with the previous work of the TTO.

Implementing a dramatic program of changes regarding the handling of technologies by the technology transfer office could have faced challenges within the university, much like other large organizations attempting programs of change. Based on the observed outputs, the notion that there would be no substantial change (H1) is disproven. This is an important observation because it is a reasonable notion that reworking such a fundamental aspect of university output could be expected to be difficult, or even impossible.

Concerns over resistance can be followed by the notion that attempting to implement a dramatic program of changes within the technology transfer office could induce a substantial decrease in measured outputs (H2). This might have arisen through internal faculty push-back, or externally via businesses not accepting the proposed changes. However, the data consistently show outputs

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that have not decreased. Administrative agreements remained largely consistent, and licensing and new company formation activities increased. This H2 can be said to have been rejected. One notable exception was that Letter Agreements dropped by two-thirds. The reasons will be discussed under the analysis of H4 below.

In the face of dramatic shifts in practices and procedures, there were no substantial objections reported. Indeed, the office was more rigorous about filing patents, and efforts were to be focused more on those technologies that seemed most capable of commercialization. While research funding increased, as did the number of invention disclosures, the patent applications largely remained flat. The application of more-rigorous standards might have been expected to induce resistance. By definition this may have included rejecting the filing of patent applications from invention disclosures by senior faculty. Locally there may have been individual cases where an inventor was not happy with a decision to not proceed to patent, but the observed outcomes are that patent applications per unit of research funding decreased, without any university-wide push-back from faculty.

In the context of a large and sophisticated university, implementing ‘change’ may not be enough to produce substantial impact on outputs. UC San Diego had previously introduced the ‘Express Licensing’ program, and it had been successful, but the impact was not dramatic. It was therefore reasonable to question whether the implementation of a program of changes within the technology transfer office, if it did induce an increase in measured outputs, such increase will not be substantial or at best only in line with any change in research funding (H3). It is important to note that during the period of study, research funding increased by nearly a third, and disclosures increased by a largely equivalent amount. It is of note that the implementation of the Frictionless program did not increase the number of disclosures per unit of research funding. Were substantially all inventions being reported prior to the Frictionless program being introduced? There was considerable outreach to researchers as part of the program, and the need to disclose inventions was inherent in many of those communications, so does a different approach need to be taken to extract more inventions from the research community? Or is the implication that the university had established procedures that ensured effectively all inventions were disclosed? More broadly, following the implementation of the Frictionless program, changes in measured outputs did occur, and the increase was substantially above the change in research funding. Accordingly, H3 is rejected. A substantial increase in licensing activity, and new company formation, was observed. Both non-exclusive and exclusive patent and material licenses increased, and the output per ICM increased substantially.

From studies in the finance industry, it has been observed that indicators of performance outcomes are important, but there is a risk that the measured indicators and outcomes, rather than the underlying value drivers, can become the priority for employees. Problems can arise if a worker realizes it is in their best interest to maximize the measured outcomes, even if value is wrecked in the process (Kaiser and Young, 2018). Accordingly, it was questioned whether, if there are increases in measured outputs, such increase will be skewed towards the easiest transactions (H4). There is clear evidence that the program of changes examined in this study may be associated with increased outputs. Non-exclusive and exclusive patent and materials licenses increased substantially, as did non-exclusive copyrights licenses. Start-up companies increased by around half, which was less than other licenses, but when adjusting for the deal time necessary to conclude a transaction, start-up company output per ICM nearly doubled. Start-up company formation was encouraged and closely measured, and also incentivized under the Frictionless program. In contrast, non-exclusive licenses did not see specific programs aimed at adjusting the upfront costs of licensing, and the license structure remained substantially unchanged. The observed outputs in non-exclusive material and patent licensing show a sizable increase, and yet these licenses are not as quick to complete as non-exclusive copyright licenses, and they are not the consequential start-up licenses. This suggests that outputs increased broadly, and not just along paths of least resistance. Whether this is connected with being 'open for business' may have been a more-important aspect of the Frictionless program than might have been anticipated, or if a well-motivated team may increase their outputs broadly, are questions deserving further study. The increase in start-up companies is notable, given the workload is almost twice that of an exclusive or non-exclusive patent or material license, and five-fold that of a copyright license. With the increase in non-exclusive copyrights licenses, which have a lower median deal-time than other transactions, it may be questioned whether this does partially prove H4. The concurrent increase in the more-burdensome transactions does not lend support to this assertion. One notable exception was that Letter Agreements dropped by two-thirds, which does suggest a potential shift directly into more substantive transactions. There are indications that start-ups take subsequent additional licenses; in effect generating a positive multiplier for licensing activity. This will be discussed further in a subsequent study.

Given that H3 has been rejected, and there is evidence both for and against H4, but there are clear increases in measured outputs, were there corresponding impacts to the local and regional economy? According to Hypothesis 5 (H5): *If H3 and H4 are disproven, and there are increases in measured outputs, there may be corresponding impacts to the local and regional economy.*

Within this study, there are suggestions that increasing technology transfer outputs may increase funding to researchers. The additional flow of research funding to faculty, and other benefits (like new flows of information, from commercial scientific advisory boards and the like) need further study. Within this single study site, it may take several years for the data to become available. New technologies are invented, they are reported to the technology transfer office, a patent is drafted and submitted, the new technology is advertised, and expression of interest is made, a negotiation for a license is conducted (with median times reported in this study), and the license is executed. Following this, the licensee might draft a Small Business Innovative Research ("SBIR") funding application, submit the application at the next tri-annual deadline, and await the notice of award of funding (typically nine months to a year). Upon the notice of award of funding, the licensee may reach out to the university, via the faculty-inventor, and indicate desire to complete a subaward to the university. Subaward documents are substantially governed by guidance from the federal funding agency, and are therefore typically quick to complete. Funding may be staged over the period of performance of the subaward, which might be three-to-six months, but could be longer. End-to-end, from invention disclosure to banking a final payment for research conducted under a subaward, the quantitative funding output measure may easily take two years or longer to be available. The financial impact may be substantial, but delayed. Moving from a single laboratory to the wider scale of a university, each license completed and company initiated may cumulatively alter the academic and economic trajectory of the university. This conforms to the suggestion that the modulation of inputs may indeed lead to changes in outputs, as suggested by Bercovitz, Feldman, Feller, and Burton (2001).

Output per unit of research funding is a complex calculation. In this study we have used units of output (licenses, etc) per one hundred million of research funding in that year. However, in any given year, licenses are being taken to technologies that were funded some time ago. Indeed, a substantial proportion of licenses are taken on technologies more than seven years old (internal data). As such, comparing number of licenses to the current year's research funding may be an incomplete study. If many licenses are the product of funding from 3-5 years ago, then obviously there is not a direct correlation between licenses completed in a given FY and the new research funding obtained in that FY. This is worthy of separate study.

In terms of wider economic impact, the output per research Dollar increased by more than a quarter; within the context of a billion Dollar research budget, this represents a significant increase. Exclusive licenses tend to be the most complex transactions, but also are amongst those most likely to have substantial economic impact (like new job openings, or sales taxes). Even with their complexity, exclusive licenses increased in number. The wider economic impact deserves investigation.

For newly formed start-up companies, these are amongst the most-complex transactions, and they increased by more than fifty percent. Starting a new company is a risky undertaking. The tolerance for economic risk differs systematically both across individuals and time (Sahm, 2008). As a complex licensing process, and with some degree of personal exposure to the founders, this suggest that Frictionless worked. In the wider economic context, start-ups can raise external capital. They can raise money and create an economic trajectory that is much less likely with a non-exclusive license to a technology.

Founders of new companies are often the people who discovered or invented the technology being commercialized. By definition, they know the technology best. The undertaking is more of a scientific or technical project than a complicated business, at least in the early stages of the company. Therefore, if an inventor is a PhD candidate, how do we ensure that the discovery moves into a company, so that it might be efficiently developed? How do we ensure that the output is not inhibited by the risk tolerance of the inventor? There are indications that economic risk tolerance has a component of difference due to gender and ethnicity, but risk tolerance for a single individual may be constant across their life (Sahm, 2008). This raises some key questions. If there are differences in economic risk tolerance (for starting a new company) due to economic circumstances, ethnicity, or gender, how do we overcome that? To quote Astebro and co-workers: "the gross flow of start-ups by recently graduated students with an undergraduate degree in science or engineering is at least an order of magnitude larger than the spin-offs by their faculty, that a recent graduate is twice as likely as her Professor to start a business within three years of graduation, and that the graduates' spin-offs are not of low quality" (Astebro, Bazzazian, and Braguinsky, 2012). Who is starting the companies? This is worthy of further study.

In the wider community, during the period of study the San Diego region went from broadly averaging $1-2 billion Dollars in regional venture funding per year, to close to $9 billion Dollars by the end of the 2021 calendar year. Clearly correlation is not necessarily causation, but large clusters of innovative activity (like Silicon Valley) are often co-located near elite universities (like UC Berkeley and Stanford). This is suggestive that the two are not entirely mutually exclusive. It has been identified that there may be direct links between transforming university goals and practices in the area of start-ups, and the stimulation of entrepreneurial economic development (Astebro, Bazzazian, Braguinsky, 2012). Such a dramatic increase in regional venture funding at the same time that there is a substantial increase in university technology outputs (particularly new companies) is deserving of further investigation.

In summary, a program of change was successfully implemented at a large research-intensive university. This study captures the last year before Frictionless began, and the first year where all changes (up to that point) had been implemented and there was constancy in practices for one year. It can be challenging to implement change in large organizations. At the time of initiation, the expected outputs could not readily be estimated. Ultimately the evidence suggest that the goals were exceeded. Following on from the examples of institutional programs at research-intensive universities like Carnegie Mellon and the University of Michigan, UC San Diego implemented its own program of change. It was unusual because it was so dramatic; such a broad range of new programs, all implemented in such a short space of time. Yet outputs broadly increased, without substantially skewing towards easier transactions. One interesting observation is that new start-up companies becoming repeat licensees, potentially creating a 'positive feedback loop'.

Many questions remain. Has the university 'lost money' in pursing the Frictionless program? Indeed, even if it did, should a public university be a profit-seeking entity? Is the Frictionless program sustainable? Either through funding or new sources of information, did faculty gain an improved experience? Was there a real wider economic effect of the increased outputs from the university? Finally, this study provides evidence supporting the notion that a program of change may be successful, and therefore could in theory be a template for other universities to attempt. Thus, perhaps most importantly of all, could such a program of changes be implemented successfully at other institutions?

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ABBREVIATIONS

AIM = Accelerating Innovations to Market

AUTM = Association of University Technology Managers

FTE = Full-time equivalent

FY = fiscal year, a period running July 1 to June 30.

GAO = United States Government Accountability Office

ICM = Innovation and Commercialization Manager

LLC = Limited Liability Company

NCI = National Cancer Institute

OIC = Office of Innovation and Commercialization, UCSD

SDSC = San Diego Supercomputer Center

SBIR = Small Business Innovative Research

TTO = Technology Transfer Office

UC = University of California

UCOP = University of California Office of the President

UCSD = University of California San Diego

CONFLICT OF INTEREST STATEMENT

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