Sustaining and disruptive categorisation of university-licensed technologies: the impact on licensee and university technology revenue stream

Ali Yassine

Department of Industrial and Enterprise Systems Engineering,
University of Illinois,
313 Transportation Building,
Urbana, Illinois 61801, USA
E-mail: yassine@uiuc.edu

Ikhlaq Sidhu

Centre for Entrepreneurship and Technology,
University of California, 3117 Etcheverry Hall,
Berkeley, California 94720, USA
E-mail: sidhu@berkeley.edu

Joe A. Bradley*

Department of Industrial and Enterprise Systems Engineering,
University of Illinois,
304 Transportation Building,
Urbana, Illinois 61821, USA
E-mail: jabradly@illinois.edu
*Corresponding author

Abstract: In this paper, we propose a conceptual framework which considers how the categorisation of a technology as sustaining or disruptive by the university technology management office during screening may impact the licensee, number of expected years until success, and potential net income to the university. We test this framework on 135 patented or copyrighted technologies assigned to the University of Illinois, Urbana-Champaign (UIUC). Initial results indicate that sustaining technologies are most likely licensed to market leaders and disruptive technologies had equal likelihood of being licensed to either a market leader or a start-up.

Keywords: university technologies; sustaining; disruptive; start-ups; established firms; technology transfer; university technology transfer offices.

Reference to this paper should be made as follows: Yassine, A., Sidhu, I. and Bradley, J.A. (2010) 'Sustaining and disruptive categorisation of university-licensed technologies: the impact on licensee and university technology revenue stream', *Int. J. Technology Transfer and Commercialisation*, Vol. 9, No. 3, pp.217–237.

Biographical notes: Ali Yassine is an Assistant Professor at the Department of Industrial and Enterprise Systems Engineering (IESE) at the University of Illinois at Urbana-Champaign (UIUC). His research involves managing the development process of complex engineering systems, design process modelling, and IT-enabled concurrent engineering. Prior to joining UIUC, he was a Research Scientist at MIT Center for Technology, Policy and Industrial Development (CTPID) during 1999–2002. He received his BE in Mechanical Engineering in 1988 from the American University of Beirut. He received the MS and PhD in 1989 and 1994, respectively, in Industrial and Manufacturing Engineering from Wayne State University in Detroit, Michigan.

Ikhlaq Sidhu is an experienced educator, scholar, high-technology executive, and innovator. He is currently the Executive Director and Adjunct Professor at the Center for Entrepreneurship and Technology at University of California, Berkeley. Previously, he held faculty and centre director appointments in the College of Engineering at the University of Illinois. At UIUC, he built a 1000 student engineering entrepreneurship program. He has also served in senior executive and technology leadership positions at US Robotics Corporation, 3Com Corporation and Cambia Networks. He received his Bachelor's Degree in Electrical and Computer Engineering from the UIUC, and his Masters' Degree and Doctorate in Electrical Engineering from Northwestern University.

Joe A. Bradley is a PhD candidate in the Department of IESE at the UIUC. He has five years of experience in the software and consumer products industries. He received an MBA from the UIUC, an MS in Mechanical Engineering and a Minor in Electrical Engineering both from Iowa State University, and a BSE in Aerospace Engineering from the University of Michigan at Ann Arbor.

1 Introduction

Since the passage of the Bayh-Dole Act of 1980, many universities have increased their efforts and activities in technology commercialisation of university-based technologies. Some of these technologies are licensed to start-up companies and others to market leaders as well as companies of various sizes and market positioning. One of the key challenges of technology transfer for the university is that most technologies are not immediately ready for commercial applications. They are typically demonstrated for proof of concept at a small-scale. Consequently, many of the development issues regarding commercialisation have yet to be addressed. By framing our analysis within the concepts of disruptive and sustaining technologies, we study the patterns of licensing and the subsequent success or failure of a technology. The objective of this paper is an exploratory study to understand the impact of the sustaining or disruptive characterisation of a technology and its impact on a licensee, expected number of years until the technology becomes a success, and finally the overall income received by the university. Therefore, we propose a simple conceptual model that elucidates a relationship between technology categorisation, technology licensee, and potential revenue streams for university-licensed technologies. Although many of the theories and concepts discussed in this paper regarding sustaining and disruptive technologies are not new, we believe that the application to university-based technologies is new and is therefore an interesting area for exploration.

The work by Christensen (1997) detailed the key differences between disruptive and sustaining technologies. Sustaining technologies have attributes more akin to improvements in the current state-of-the-art. The improvement could be either incremental or discontinuous. A sustaining incremental improvement uses the same basic technology but does it faster, better, or cheaper. A sustaining discontinuous improvement uses a significantly different technology or knowledge, but basically provides the same value to the same or similar market need. A sustaining improvement is intended to increase the competitiveness of a product. Examples in this category include

- improvement in disk hard-drive capacities
- improvement in resolution for photo-cameras or sensors
- increasing bandwidth for communication technologies.

Alternatively, a disruptive technology provides a ‘new-use’ category for a technology that was previously unavailable. These technologies reconfigure existing state-of-the-art technology to serve new users or create new applications. Often cheaper and simpler, disruptive technologies make new markets possible even though they are not better than the current state-of-the-art technology in every way. They initially satisfy the needs of smaller niche markets prior to becoming mainstream accepted. Examples of such technologies include

- Records replaced by Compact Disk
- Film cameras replaced by Digital Images
- Inkjet vs. Laser printing.

The initial results of our study on the impact of the categorisation of these technologies indicate that successful sustaining technologies are most likely licensed to market leaders. Furthermore, the successful disruptive technologies were more likely licensed to market leaders. This is a departure from the theoretical expectations. We suspect that the Office of Technology Management (OTM) systematically treats technologies primarily as sustaining when, in fact, having a dual technology classification approach might provide better identification of the appropriate commercialisation channel in the long run. Additionally, we find that disruptive technologies had equal likelihood of being licensed to either a market leader or a start-up and that the most successful disruptive technologies were licensed to market leaders. We also observed that the time to success after licensing of disruptive technologies was shorter than that of sustaining technologies in terms of the payback period to the university. This seems to support the argument that disruptive technologies can eventually leapfrog sustaining technology as they achieve comparable or better price/performance parameters than the leading incumbent technology for a specific market.

The remaining content of the paper is as follows. Section 2 discusses the breath of ongoing research in university-based technology commercialisation. Section 3 discusses technology commercialisation models and strategies. Section 4 discusses the methodology used for this investigation, focusing on the analysis, research design, and measurement instrument. Section 5 discusses the results and observations. We recap the hypotheses and make the case for rejection or failure to reject the hypotheses proposed at the outset. Our conclusions are discussed in Section 6, providing reasons and explanations for the departure of some results from the predicted behaviour.

2 Review of university-based technology licensing

Numerous researchers investigated university-based technology licensing (Rasmussen, 2006). Some researchers studied the impact of institutional prestige and technology licensing (Shane, 2002). These researchers noted that there was correlation between prestige, inventive history, and technology licensing. One of the key benefits extended to prestige was the mitigation of risk due to the perception of the organisation offering the technology for licensing. Others considered the impact of an organisation's endowment on the success of university start-ups (Shane and Stuart, 2002). This investigation focused more on the social-endowment (social capital) of the organisational founders. Their results showed that there was a correlation amongst the various relationships due to social networks and the impact on the success of an organisation. A founder's social network that includes venture capitalists had a better chance of obtaining finance, which can impact long-term success. There was also some work investigating university licensing patterns to understand how university inventions get into practice and use (Allan, 2001; Bradshaw et al., 2005; Colyvas et al., 2002; Mowery and Shane, 2002; Muir, 1997; Shane and Stuart, 2002; Smilor and Matthews, 2004). Randazzese (1996) explored the technology transfer of university-based CAD technologies. He suggested that technology transfer only succeeds if the licensee firm establishes organisational incentives for the technical staff to commit time and efforts to implement university technologies. Del Campo et al. (1999) analysed the commercialisation strategies for university-based medical-imaging technologies. They proposed that universities have to re-examine the incentive structure for investigators regarding publishing vs. protecting intellectual property. Additionally, other researchers considered the overall performance of university technology transfer office in meeting their stated objectives of fostering economic development. Markman et al. (2005) stated that many universities were pressured to show economic growth for the research grants given to the institution. They found that many universities saw themselves as facilitators for *new venture creation* and *economic development*. Although economic development was a goal, there appeared to be a paradoxical underpinning applying pressure to show Return On Investments (ROI) in research. This investigation found that technology offices were more and more motivated to maximise cash flows and minimise risk, which led to choices that constrained new venture creation. Lockett et al. (2005) postulated that one of the constraints on the success of spin-off firms licensing university technology was the knowledge gap between the agents involved in the transactions. These agents included the university, inventor, spin-off organisation, and the management team. They suggested that a consideration of knowledge gap could lead to a better understanding of factors that can influence the economic performance of a spin-off organisation. Siegel et al. (2003) identified a number of key environmental and organisational factors that influenced the relative productivity of university technology transfer offices. Some of these factors are

- limited resources
- time and effort
- unforced rules
- interest of industry
- reward systems.

They concluded that the most critical organisational factors were technology offices employee reward systems. Furthermore, Thursby et al. (2001) considered the outcomes of university licensing in light of diverse objectives and technology transfer offices' characteristics. There are many intriguing findings in this study. First, they found that the stage of development of a technology at licensing can impact future financial return to the university. They also found that there was only a marginal return as the number of technologies for a specific industry increases. They postulated on possible causes of this phenomenon, such as environmental factors.

A review of the best practices of university technology licensing offices focused on the operations, economic impact, and commercialisation initiatives of the organisation (Allan, 2001). One seminal paper in this area by Mowery and Shane (2002) considered the characteristics of university entrepreneurship and technology transfer. This paper focused on four themes:

- the relationship between university research and private sector innovation
- the mechanisms of technology transfer
- the evolution of university technology transfer activities
- the creation of new firms to exploit university technology.

The authors proposed a series of questions regarding the types of technologies that leads to firm formation and what types were licensed to existing firms. Shane and Stuart (2002) observed that the formations of many new ventures were predicated on the lack of strong patent protection – stronger protection suggest higher likelihood of licensing the technology to a market leader. Other papers discussed the importance of the Bayh-Dole Act on university technology transfer. Rogers et al. (2000) discussed the types of technologies that were most frequently licensed, and quantified the overall revenue earned by university-based technologies as well as the impact on society. Boettiger and Bennett (2006) considered the overall impact of the Bayh-Dole Act on economic development. They attempted to identify the winners and losers since the Act was established. Our contribution to this body of research is to explore a sustaining and disruptive nature of university-based technologies in light of current theories and ideas.

3 Technology commercialisation strategic models

The preceding literature review has considered a breath of knowledge of research in university-based technology transfer activities and behaviour. In this section, we narrow our focus, specifically, to the management and the commercialisation of these technologies. We are considering the sustaining and disruptive nature of a technology. Sustaining technologies fit well within the currently established business model. Christensen (1997) argued that a market leader was unable to effectively manage disruptive technologies. He stated that disruptive technologies were not able to meet the growth demands for the organisation. Christensen found that disruptive technologies were oftentimes developed within these organisations; however, they failed to get the attention and/or resources to support commercialisation. This argument was supported by Rice et al. (1998) who reported that the high level of uncertainty in disruptive technologies was too much for a market leader, and that disruptive innovation projects were badly aligned with the operating business reward structure. It seemed that start-up organisations were better positioned to adapt to the demands of disruptive technology commercialisation. Therefore, disruptive technologies were most often introduced by a start-up, and the start-up eventually overshoots the market leader within that specific technology category. Furthermore, Christensen discussed the successes of larger organisations that had spun-off these disruptive technologies into separate business units that were distanced from the culture of the larger organisation. Other researchers (Abernathy and Clark, 1985; Hill and Rothaermel, 2003) showed counterexamples to this phenomenon. In these cases, the incumbent market leaders survived and even thrived in the midst of radical or disruptive technology changes. Additionally, other researchers explored the impact of technological changes on the organisational environment and the magnitude of these changes on the organisation (Henderson and Clark, 1990; Tushman and Anderson, 1986). Lynn et al. (1996) considered techniques and methods to identify target markets for disruptive technologies. They suggested a probing and learning strategy to gain insight into which markets to pursue. Kassicieh et al. (2002) reported that disruptive and sustaining technologies required different commercialisation approaches and activities. If this is the case, the characterisation of technologies into one of these categories could have significant impact on long-term success.

The technologies discussed by these researchers focused on commercial industry; however, this paper specifically considers university-based technologies. As the basis of our study, we have utilised the intellectual property archive contained within the database of OTM at the UIUC. We explore the nature of the technology (sustaining or disruptive) in relationship to licensee (market leader or start-up) and to net income received by the university.

Considering the above literature on disruptive and sustaining technologies and commercialisation, we propose the following two hypotheses:

> *Hypothesis 1: University-based technologies categorised as sustaining are more likely to be licensed to market leaders.*

> *Hypothesis 2: University-based technologies categorised as disruptive are more likely to be licensed to a start-up/new venture.*

Additional arguments suggested that the high level of uncertainty led to market leaders' lack of motivation to invest in disruptive technology projects (Rice et al., 1998). Time and investment dollars will largely be allocated to sustaining technology projects that can help meet growth requirements. This implies that the established infrastructures of these organisations are not designed to successfully commercialise disruptive technologies. Christensen and Overdorf (2000) suggested that this infrastructure was entrenched in the values of the organisation. To illustrate this point, they used the example that if a company's overhead cost requires it to achieve gross margins of 40%, it will avoid a project that returns below 40%. Gilbert (2003) suggested that these technology disruptions were not an immediate phenomenon. It can take years before this new technology supplants the incumbent state-of-the-art technology. This implies that there is time for an incumbent to recognise the threat and react successfully. These arguments lead to the following hypotheses:

> *Hypothesis 3: University-based technologies categorised as sustaining are more successful if licensed to a market leader.*

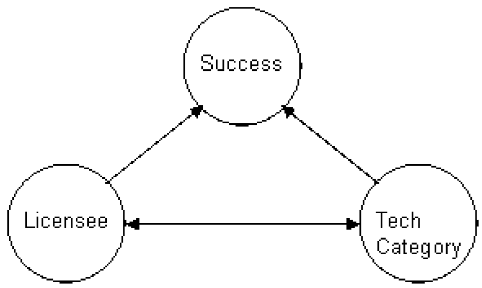
Hypothesis 4: University-based technologies categorised as disruptive are more successful if licensed to a start-up/new venture.

Christensen (1997) suggested that disruptive technology would eventually leapfrog the price/performance parameters of sustaining technologies and over time move up market into the sustaining technologies strongholds. The pace of innovation typically outpaced the customer performance requirements. This phenomenon allowed these disruptive technologies to eventually surpass sustaining technologies. Rice et al. (1998) stated that if a firm failed to sustain their competitive edge, they risk degradation of their market position. Maintaining success requires new business ventures and new products. Reinganum (1983) suggested that many incumbents have a disincentive to invest in radical new technologies. If a radically new technology is released, it could introduce a wave of new developments that can significantly alter the structure of the industry and lead to the demise of the incumbent. This argument leads to a final hypothesis:

Hypothesis 5: University-based technologies categorised as disruptive will be adopted at a faster rate and eventually supplant sustaining technologies.[1]

We summarise the above hypotheses in the conceptual model of Figure 1. This proposed model takes technology categorisation and type of licensee as inputs. The output response is identified as a measure of success (e.g., overall net income to the university). The bi-directional arrow between the *licensee* and the *technology category* suggests a hypothetical relationship between the licensee and technology categorisation (i.e., Hypotheses 1 and 2). Additionally, the conceptual model suggests that both variables (i.e., technology category and licensee) influence overall success to the technology transfer office (i.e., Hypotheses 3 and 4).

Figure 1 Hypothetical model of technology transfer



4 Methodology

4.1 Data collection

We survey 225 UIUC technologies licensed over the time period from 1980 to 2004. The population of 225 technologies is reduced to 135 owing to a lack of historical information or relevant information to the investigation. Factors stipulating exclusion from the study are:

- no useful data within the database
- information missing or not included within the database
- royalty-free agreements issued to licensee from the university.

Information on each of the technologies is archived in the OTM database. Each technology is given a rating by OTM managers based on market potential. The ratings are high potential, medium-high potential, medium-low potential, or Low potential. These ratings are based on the outcomes of an extensive screening process that all technologies submitted to OTM undergo. This screening process involves a patent and copyright search, a market potential assessment, an assessment of the technology value network, and many other activities to support the OTM staff in determining whether or not to pursue protection for a given technology (Office of Vice-President for Economic Development and Corporate Relations, 2002). Because of the nascent state of many university-based technologies, this screening method is used as an alternative to well-known methods such as ROI, 25 percent rule, or net present value for valuations (Goldscheider et al., 2002). These techniques are used to value projects or technologies when it is possible to make some estimation of the future potential cash flow by using past performance results. The transition of many university technologies to commercialisation carries risk that is difficult to quantify. The methods used by the OTM are an attempt to manage this uncertainty by looking at the commercialisation process holistically throughout the screening process.

Using these 135 data points, we suggest four analysis factors:

- technology categorisation
- success based on licensing profit
- licensee type
- number of years since the first license was executed.

The proposed model illustrates the link between technology categorisation, the licensee, and the overall success (see Figure 1).

4.2 Technology categorisation

Technology categorisation determines the classification of a technology as either disruptive or sustaining. To make this classification, we consider each technology based on two criteria:

- Is the technology an improvement or does it create a new-use?
- Are there any previously related patents/copyrights/research papers to this technology? Or was this an original patent or copyright in the field?

The classification of the technology as disruptive or sustaining is qualitative. The database that we used has details on the current state-of-the art (prior art, etc.) for each of the technologies we studied. The OTM has documented the technologies that were similar and patents or copyrights that were similar at the time the patent application or copyright registration was filed. On the basis of this information along with a description of the technology and problem that the technology is attempting to solve, we would make a judgement on whether to classify the technology as either sustaining or disruptive. Although this method is qualitative, we maintained a consistency when making the decisions regarding each technology. Table 1 shows the scale assignments and descriptions for each rating.

Table 1 Technology categorisation scales

Categorisation	*Scale*	*Description*
Disruptive	–1.0	Revolutionary new technology, new-use, seminal patent or copyright in the field
Mostly disruptive	–0.5	New usage, a key patent or copyright in the field, could be a few similar patents or copyrights at time of application
Mostly sustaining	0.5	Significant improvement, market is primarily established, potential to gain a few new users
Sustaining	1.0	Improvement that is basically replacing the current state-of-the-art

4.3 Licensing profit

The licensing profit criterion is based on the net income-to-date (royalties) for each technology. We use a 4-point scale with a range from –1 to 1 (excluding zero) as shown in Table 2.

The conversion of the revenue to a 4-point scale was to develop an analysis basis. We looked at ranges of revenue to make an assessment regarding success or failure of a technology. We used \$30,000 as a cut-off for success based on interviews with the Director of the OTM, who stated that the average cost for obtaining a patent is ~\$30,000.

Table 2 Net income scale

Net income-to-date	*Scale rating*
<\$0	–1.0
\$0–\$29000	–0.5
\$30000–\$99999	0.5
>\$100000	1.0

4.4 Licensee characterisation

The licensee characterisation is based on the market position at the time of the licensing agreement. In some cases, the start-up that held the original license had been subsequently acquired by a market leader at the time of this study. We attempt to account for that by looking at the position of the licensee within the specific industry that this technology would be used. For example, organisation 'X' may not be one of the largest suppliers (market leader) for microprocessors; however, they are the leader in real-time programmable processors. In this case, if the technology under consideration discusses a technology for programmable processors and it is licensed by organisation 'X', we will consider this as licensed to the market leader in that specific industry segment. We used a 2-point scale with values from –1 to 1. Table 3 shows the scale assignments.

Table 3 Licensee market position scale

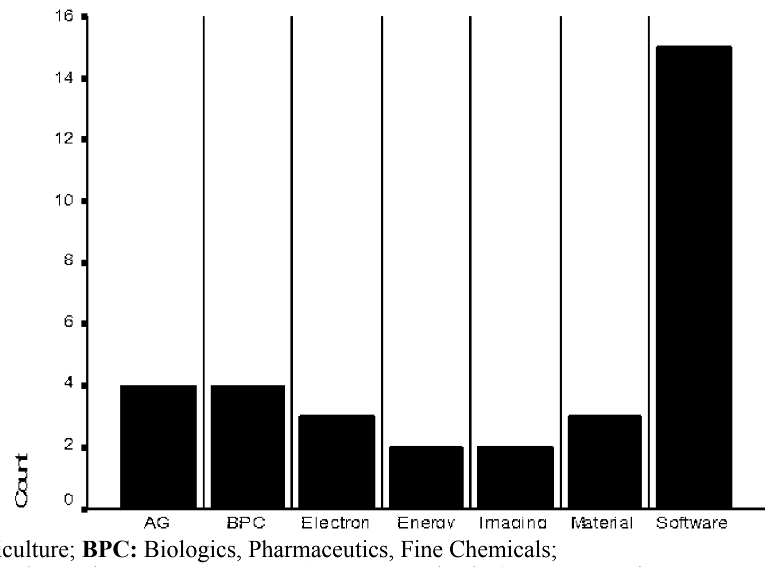
Licensee market position	*Scale rating*
Market leader	1.0
Start-up	–1.0

The market leaders are determined based on the sales revenue and market share within the specific industry segment. In some cases, tracing the historical information regarding market position was challenging. For more recent licenses (less than ten years), we use information contained in business resource databases (e.g., One Source, Hoovers). On the basis of this information, we determine whether or not the organisation is or is not a leader. In the case of a start-up, we took the position that if the formation of the organisation was exclusively based on licensing the technology from the university, then the organisation is a start-up. We use these classifications to provide an effective differentiator between the organisations used in this study.

4.5 Data summary

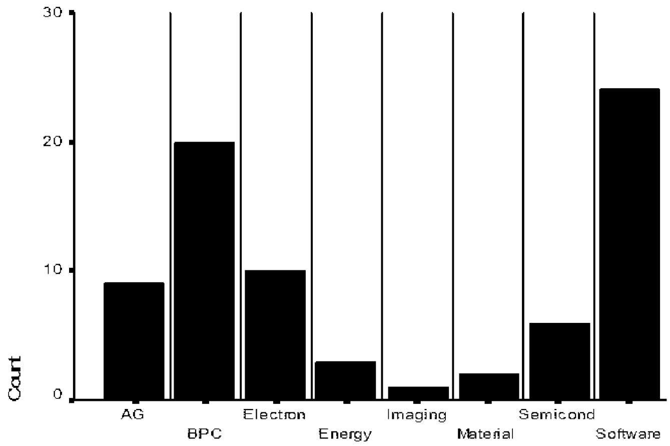
On the basis of the above rules and classifications, we have classified 102 technologies as sustaining and 33 technologies as disruptive. The technologies are separated into nine technology categories. Figure 2 shows the categorisation for the disruptive technologies. Figure 3 shows the categorisation for the sustaining technologies. Figure 4 shows the categorisation for all the technologies.

Figure 2 Disruptive technologies



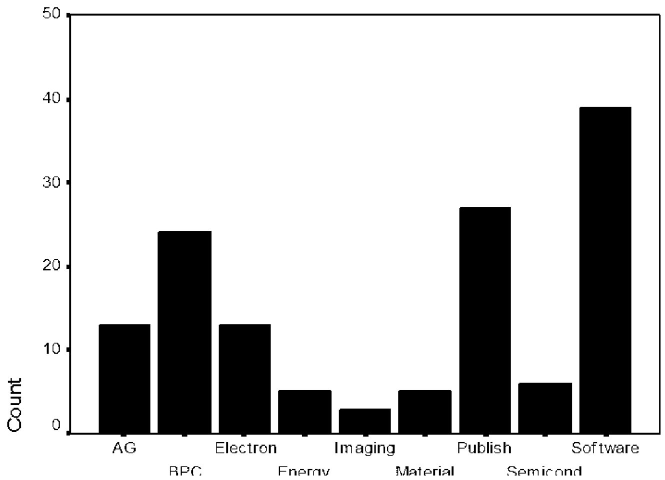
AG: Agriculture; **BPC:** Biologics, Pharmaceutics, Fine Chemicals;
Electron: Electronics; **Energy:** Energy; (Storage, Production) **Imaging:** Microscopy, Fluorescents; **Material:** Materials, Metallurgy, etc; **Publish:** Books, Magazines, TV Media; **Semicond:** Semiconductor; **Software:** Software.

Figure 3 Sustaining technologies



AG: Agriculture; **BPC:** Biologics, Pharmaceutics, Fine Chemicals;
Electron: Electronics; **Energy:** Energy; (Storage, Production) **Imaging:** Microscopy, Fluorescents; **Material:** Materials, Metallurgy, etc; **Publish:** Books, Magazines, TV Media; **Semicond:** Semiconductor; **Software:** Software.

Figure 4 All technology categories



AG: Agriculture; **BPC:** Biologics, Pharmaceutics, Fine Chemicals;
Electron: Electronics; **Energy:** Energy; (Storage, Production) **Imaging:** Microscopy, Fluorescents; **Material:** Materials, Metallurgy, etc; **Publish:** Books, Magazines, TV Media; **Semicond:** Semiconductor; **Software:** Software.

It is not always possible to identify the immediate market for a university-based technology. We have accounted for this by using the information in the OTM database and the classification system of the patents issued by the US Patent and Trademark Office (USPTO). The technology classifications (e.g., AG, BPC, Software, etc.) are based on the patent categories assigned by the USPTO for specific technology areas. This classification scheme was used to identify an appropriate market.

5 Results

5.1 Analysis of licensee and technology categorisation

Tables 4 and 5 show frequency data describing the number of sustaining and disruptive technologies licensed to a specific category of licensee (e.g., market leader, start-up). Analysis based on frequency values show that sustaining technologies are licensed to market leaders in 74% of the cases and to start-ups in 26% of the cases. Technologies classified as disruptive are licensed to market leaders in 52% of the cases and to start-ups in 48% of the cases. This result suggests that disruptive technologies licensed from the university have equal likelihood of being licensed to market leaders or start-ups. These initial results support Hypothesis 1 (*University-based technologies categorised as sustaining are more likely to be licensed to market leaders*), but do not provide any conclusive evidence for Hypothesis 2 (*University-based technologies categorised as disruptive are more likely to be licensed to a start-up/new venture*). For all cases, we observe that 62% of the technologies were licensed to market leaders and that 38% were licensed to start-ups. Compliance with the Bayh-Dole Act to facilitate growth of start-up organisation by licensing university-based technologies when possible could be a reason for this considerable percentage of licenses awarded to start-ups.

Table 4 Licensee for sustaining technologies

Scale values	*Frequency*	*Percentage*
−1.00	27	26.4
1.00	75	73.6
Total	*102*	*100.0*

Table 5 Licensee for disruptive technologies

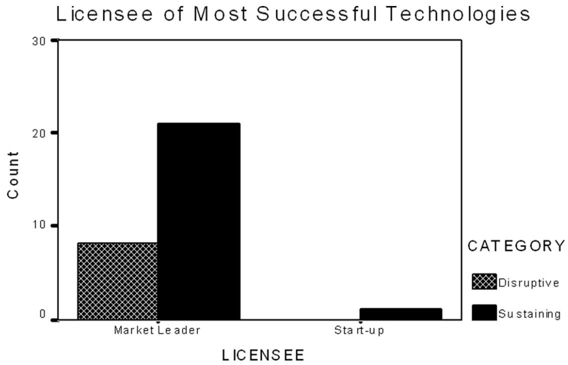
Scale values	*Frequency*	*Percentage*
−1.00	17	51.5
1.00	16	48.5
Total	*33*	*100.0*

5.2 Analysis of licensee and years of licensing for most successful technologies

In considering a conditional analysis of the data, we analyse only the technologies that we considered to be ‘big-winners’. We defined ‘big-winners’ as technologies with net income greater or equal to $100,000, which is typically a value 3-times the expenditure to apply for a patent.

We observe that 96% of the ‘big-winners’ categorised as sustaining technologies are licensed to market leaders. The disruptive technologies are exclusively licensed to market leaders as well. These findings appear to support Hypothesis 3 (*University-based technologies categorised as sustaining are more successful if licensed to a market leader*), but do not provide support for Hypothesis 4 (*University-based technologies categorised as disruptive are more successful if licensed to a start-up/new venture*). Figure 5 shows the results for the ‘big-winners’ subgroup. In this figure, we observe that the vast majority of most successful technologies were licensed to market leaders. These results seem to support the findings of Markman et al. (2005), which suggest that universities would tend to license to a market leader to maximise short-term profit and show return on research grants.

Figure 5 Characteristics for 'big' winner technologies



The average number of years the technology has been licensed from the university for the 'big winners' is 10.0 years with a standard deviation of 6.1 years. Partitioning this group into disruptive or sustaining classifications, we find that the average number of years for sustaining technologies is 10.5 years with standard deviation of 6.6 years and for disruptive technologies the average is 8.8 years with standard deviation of 4.3 years. These results seem to provide some support for Hypothesis 5 (*University-based technologies categorised as disruptive will be adopted at a faster rate and eventually supplant sustaining technologies*). For each case, we assume that the average number of years the technology has been licensed is the same as the number of years to success. If we carry this assumption, the results provide support for the findings by Christensen (1997). His results suggested that disruptive technologies could gain a critical mass and eventually supply the market.

5.3 Analysis of licensee, years of licensing, success or failure of technology

We divided the remaining (excluding the big winners) technologies into sustaining or disruptive technology categories. For the sustaining technologies, we observe that 67% of the technologies are licensed to market leaders and 34% are licensed to start-ups. This seems to provide supporting evidence for Hypothesis 1. Regarding disruptive technologies, we observe that 59% are licensed to start-ups and 41% to market leaders. We now find that there is some supporting evidence for Hypothesis 2, unlike in the case for the 'big winners'. When we further partition this data subset into those technologies that are marginally successful (net income between $30000 and $99999) and those that fail (net income $29000 or less), we find that successful sustaining technologies are licensed to market leaders in 86% of the cases and to start-ups in 14% of the cases. This was similar to the results observed for the 'big-winner' subgroup. This seems to provide supporting evidence for Hypothesis 3. On the other hand, we find that the successful disruptive technologies were licensed to market leaders in 55% of the cases and to start-ups in the remaining 45%. This is comparable to the findings for big winners.

Consequently, there is no evidence to support Hypothesis 4. If we now consider those technologies that fail, we find that the unsuccessful disruptive technologies are licensed to start-ups in 55% of the cases and to market leaders in the remaining 45%. Additionally, we find that unsuccessful sustaining technologies are licensed to market leaders in 55% of the cases and to start-ups in 45% of the cases. Overall, we speculate that the failure of both disruptive and sustaining technology is equally likely whether it is commercialised through a market leader or through a start-up.

5.4 Analysis of technology categorisation, years of licensing, and diffusion

We realise that the results could be significantly biased by the length of time a technology had been licensed from the university; therefore, we considered descriptive statistics based on the number of years since license execution through 2004. In considering all the technologies analysed in this study, the average number of years of licensing was 7.0 years with a standard deviation of 5.1 years. For the sustaining and disruptive technologies, the average numbers of years of licensing were 7.4 years with a standard deviation of 5.4 years and 6.1 years with a standard deviation of 4.3 years, respectively. Now separating the technologies based on whether or not they were successful or unsuccessful, we note that the average number of years of licensing for a successful technology was 8.4 years with a standard deviation of 5.4 years. For the successful technologies, sustaining and disruptive technologies' average number years of licensing were 8.8 years with a standard deviation of 6.1 years and 7.1 years with a standard deviation of 4.3 years, respectively. For the unsuccessful technologies, the sustaining and disruptive technologies' average numbers of years of licensing were 7.5 years with a standard deviation of 4.6 years and 5.9 years with a standard deviation of 4.1 years, respectively. On the basis of these outcomes, we can suggest that there is approximately a 7-year success threshold for disruptive technologies and approximately a 9-year threshold for sustaining technologies. These findings lend additional support to Hypothesis 5. It is important to note that the threshold values discussed above relates only to the university's income (based on our classification) not to the overall market success of a technology. For example, a licensed technology could become profitable for a licensee after 3 or 5 years, but the royalty agreement with the university could possibly not pay large disbursements for additional years in the future, depending on the licensing agreement. An additional interesting speculation based on these results is that disruptive technologies are more quickly valuated in the market (7 years) as opposed to sustaining technologies (9 years).

5.5 Wilcoxon and t-test data analysis

Many of the aforementioned analysis used descriptive statistics. Whereas these statistics have been instrumental as an initial test of the hypotheses, we now consider the significance of these values using a *t*-test and the Wilcoxon Sign Rank Test. Figures 6 and 7 show the results of the 1-sample *t*-test and the Wilcoxon test. In these analyses, we consider the type of licensee (e.g., market leader, start-up) and the level of success of the technology. We consider these two factors as most critical to the overall success of a university technology transfer office. For disruptive technologies, the hypothesis test is $H_o = -0.5$ and $H_a > -0.5$. For sustaining technologies, the hypothesis test is $H_o = 0.5$ and $H_a > 0.5$. With a significance cut-off value of 0.05, there is evidence that leads to not rejecting the null hypotheses for sustaining technologies (i.e., Hypotheses 1 and 3), but rejecting the null hypotheses for disruptive technologies (i.e., Hypotheses 2 and 4).

Figure 6 Disruptive technologies-hypothesis testing

	Descriptive Statistics			
	N	Mean	Std. Dev.	Std. Err.
LICENSEE	3 3	**-0.076**	0.8208	0.1429

DISRUPTIVE TECHNOLOGIES							
	t-Test Analysis						
	N	Mean	Std. Dev.	Std. Err.	t	df	p-value
LICENSEE	33	-0.076	0.8208	0.1429	2.969	32.000	**0.003**

DISRUPTIVE TECHNOLOGIES						
	Wilcoxon Sign Rank Analysis					
	N	N < -0.5	N = -0.5	N > -0.5	Median	p-value
LICENSEE	33	11	6	16	-0.5	**0.001**

Figure 7 Sustaining technologies-hypothesis testing

	Descriptive Statistics			
	N	Mean	Std. Dev.	Std. Err.
Licensee	102	**0.338**	0.7077	0.0701

SUSTAINING TECHNOLOGIES						
	Wilcoxon Sign Rank Analysis					
	N	N < 0.5	N = 0.5	N > 0.5	Median	p-value
LICENSEE	102	27	40	35	0.5	**0.994**

SUSTAINING TECHNOLOGIES							
	t-Test Analysis						
	N	Mean	Std. Dev.	Std. Err.	t	df	p-value
LICENSEE	102	0.338	0.7077	0.0701	- 2.30 9	101.00 0	**0.988**

6 Discussions and conclusion

This investigation examines technology commercialisation outcomes by considering the sustaining and disruptive nature of 135 patented or copyrighted technologies at the UIUC. On the basis of our classification scheme, we have identified 102 sustaining technologies and 33 disruptive technologies. The total number of years these technologies have been licensed from the university range from less than one year to 24 years. Our statistical analysis shows that sustaining technologies are more likely to be licensed to a market leader and are likewise more successful. However, for disruptive technologies the results are inconclusive. They indicate that disruptive technologies are more successful if licensed to a market leader with the exception of a few marginally successful technologies (see Section 5.3) licensed to start-ups. This departure from the expected behaviour could be the result of many start-ups attempting to market their licensed disruptive technologies within the same channel by which the current sustaining technology are marketed. In the case of sustaining technologies, the market knows what to expect. In the case of disruptive technologies, the market readiness may not be there and the technology could be prematurely implemented in some markets.

Furthermore, the results suggest that the number or years until success after acquiring a license was shorter for successful disruptive technologies. This agrees with the findings by Christensen (1997) that disruptive technologies eventually were able to surpass incumbents owing to the faster growth rate. We also note that there was a very small positive correlation between success and the number of years since the licensing agreement; however, the evidence was not overwhelming. The results indicate that there is approximately a 7-year threshold for successful disruptive technologies and a nine-year threshold for sustaining technologies to become financially successful for the University of Illinois OTM.

Additionally, the licensing activities for the university are governed not only be revenue potential but also by other public good concerns and initiatives. Unlike corporations, universities have a mission to ensure that technologies developed by their researchers are used to benefit society even if significant revenue is not generated. If the technology transfer office has a technology with an application for non-profit organisations, the university is motivated to offer a license to the organisation even if the royalty rate is small. However, recent literature suggests that university technology transfer offices are also motivated by maximisation of cash flows (Markman et al., 2005).

Furthermore, two conditions were identified that could have possibly biased the data and led to the observed departures from current theory:

- only recently (less than five years) has the University of Illinois provided assistance for start-ups
- the University of Illinois had originally used outside patent management firms to license technologies.

These outside firms focused on licensing the technology exclusively to pre-existing companies.

Another possible challenge in this investigation is the use of $100,000 as a criterion for ‘big winners’. Within the larger scheme of technology transfer royalties and payments, $100,000 is a very modest threshold for big winners. However, the $100,000 threshold was used for the purpose of data analysis and because it was at least three times the average cost to secure a patent.

In this study, we do realise that we have taken considerable liberties and assumptions in developing our conceptual model. Our hope, however, is to elucidate the potential value of categorising university technologies along these dimensions during screening. Such categorisation can provide an additional tool for university technology transfer offices in their efforts to transfer technologies out of the university.

6.1 Generalisability and limitation of results

One of the most significant limitations in this study is the consideration of only one institution: UIUC. To overcome this weakness, we circulated a survey[2] to 12 peer institutions to get their feedback on the five proposed hypotheses. Six universities responded to our survey.[3] Table 6 summarises the categories of technologies submitted to the respondents' technology offices. Table 7 summarises the percentages of respondents that agree/disagree with the hypotheses (i.e., propositions) stated in this paper and in the survey.

Table 6 Disclosures allocations

Category	*Disclosure submitted to technology transfer office* (%)
Life science	55
Physical science/engineering	25
Software	18
Other	2

Table 7 Response to propositions

	Agree (%)	*Disagree* (%)	*Neutral* (%)
Proposition 1	66.67	33.33	0.00
Proposition 2	50.00	50.00	0.00
Proposition 3	83.33	16.67	0.00
Proposition 4	50.00	50.00	0.00
Proposition 5	0	83.33	16.67

As anticipated, most university technology transfer offices do not have a sustaining or disruptive categorisation of their technologies during screening. However, given our definition of sustaining and disruptive categorisation explained in the survey, the responding institutions were able to provide some insight and validation to our study. Some key observation that we found intriguing were the types of technology disclosures (i.e., engineering, software, and life science) submitted to the technology transfer office and the responses to the survey questions. When asked about licensing sustaining technologies, most respondents agree that such technologies were typically licensed to market leaders (Hypothesis 1). However, regarding disruptive technologies there was an equal number of respondents who agreed as well as who disagreed with our findings (Hypothesis 2). One respondent stated that technologies that they would categorise as disruptive were overwhelmingly licensed to start-up firms with the exception of some disruptive biotech and/or life sciences technologies. One respondent mentioned that owing to a dryer pipeline of biotech technologies, they have found greater interest from market leaders seeking earlier stage technologies.

When considering the success of a technology, most respondents agreed that the successful sustaining technologies were licensed to a market leader (Hypothesis 3). However, there was no consensus on whether or not the successful disruptive technologies were licensed to start-ups (Hypothesis 4). Most respondents speculate that successful disruptive technologies were most likely licensed to start-ups, but there was no concrete data to support the assertion. When asking the respondents about the payback[4] periods, we find that owing to the different operational structures,[5] this hypothesis was very difficult to gain any validation. The technology transfer office operational structures would determine how and when license agreement payments are made to the technology transfer office.

We also partitioned the surveys along the dimension of similarities and differences amongst institutions. We initially suspected that the University of Michigan-Ann Arbor would be very similar to the UIUC in their responses to the survey as a result of similar engineering program rankings and research programs, but we find noticeable differences. Upon further reflection of these differences, we observed that the distributions of technology disclosures between the two institutions were very different. Michigan's disclosures are slightly favouring life sciences – apparently because they have a large medical school. This phenomenon has been investigated by other researchers (Colyvas et al., 2002; Sine et al., 2003). They have found that a medical school can have considerable impact on technology transfer at a research institution. We find that the University of Illinois-Chicago, who has the majority of their disclosure from the life sciences, responses are quite parallel to those of Michigan. However as a counterexample, we find that Johns Hopkins, which has a majority of disclosures from the life sciences, seems to have different responses than that of both Michigan and University of Illinois-Chicago. We speculate that these differences could be due in part to the operational structure of the technology transfer office and/or the type of institution (private vs. public). These are purely speculative in light of the fact that we did not ask for any information on the organisational structure of the technology transfer office. However, we do find some literature that discusses difference and similarities amongst private and public universities and technology transfer characteristics (Sine et al., 2003; Markman et al., 2005; Siegel et al., 2003; Thursby et al., 2001). Furthermore, we observed that Stanford University's technology transfer activities seem to reflect the current theories regarding disruptive and sustaining technologies proposed by Christensen (1997). They reported that the successful sustaining technologies are licensed to market leaders and successful disruptive technologies are licensed to start-ups.

These surveys both support as well as counter some of the results of this investigation. Overall, we believe that these surveys do shed some light on the possible importance of framing university technologies along sustaining and disruptive technology dimensions.

6.2 Impact on practice

As a result of the study, the University of Illinois-Urbana/Champaign has implemented an evaluation of the technology categorisation of all technologies screened by the office going forward. They plan to implement and possibly modify the marketing strategy for technologies based on the disruptive or sustaining nature of the technology. A selection option for disruptive and sustaining technology has been added to their technology database. This will allow technologies within the database to be sorted based on these technology characteristics and compared to the marketing activity, licensee, and net income for future analysis. This implementation at the university will provide further insights of the impact of technology characterisations on university-licensed technologies.

6.3 Extensions and future research

This exploratory study provides some initial insight into the performance of university-based technologies, when considered within a context of their disruptive and sustaining nature. However, we believe that this investigation has only taken a snapshot of the volume of research opportunities available within this framework for university-based technologies. Extensions of this research could consider the impact of sustaining or disruptive technologies on royalty rates. Furthermore, a more qualitative examination of the technology including feedback from the licensee would provide a more holistic analysis. The results of this study have demonstrated to some degree that sustaining technologies are most often licensed to market leaders and seem to fair better financially within these organisations. However, for disruptive technologies, we observe a departure from the predicted behaviour or find that the results are inconclusive.

Acknowledgement

The authors thank Michael Fritz, Delphine Kranz, Lesley Millar, and the UIUC OTM for access to the data in their intellectual property database and for their time to conduct interviews. We would also like to thank Michael Cohen (University of California-Berkeley), Mary Dicig (University of Illinois-Chicago), Katharine Ku (Stanford University), Robin Rasor (University of Michigan), Jill Sorenson (Johns Hopkins University), and Alan Paau (University of California – San Diego) for their responses to our survey. Additionally, we would like to thank Don Siegel and two anonymous reviewers for their invaluable feedback on an earlier draft of this manuscript.

References

Abernathy, W.J. and Clark, K.B. (1985) 'Innovation: mapping the winds of creative destruction', *Research Policy*, Vol. 14, pp.3–22.

Allan, M.F. (2001) 'A review of best practices in university technology licensing offices', *Journal of the Association of University Technology Managers*, Vol. 8, pp.57–69.

Boettiger, S. and Bennett, A.B. (2006) 'Bayh-dole: if we knew then what we know now', *Nature Biotechnology*, Vol. 24, No. 3, pp.320–323.

Bradshaw, T.K., Munroe, T. and Westwind, M. (2005) 'Economic development via university-based technology transfer: strategies for non-elite universities', *Int. J. Technology Transfer and Commercialisation*, Vol. 4, No. 3, pp.279–301.

Christensen, C. (1997) *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Harvard Business School Press, Boston.

Christensen, C. and Overdorf, M. (2000) 'Meeting the challenge of disruptive change', *Harvard Business Review*, Vol. 78, No. 2, March–April, pp.67–75.

Colyvas, J., Crow, M., Gelijns, A., Mazzoleni, R., Nelson, R., Rosenberg, N. and Sampat, B.N. (2002) 'How do university inventions get into practice?', *Management Science*, Vol. 48, No. 1, pp.61–72.

del Campo, A.A., Sparks, A., Hill, R.C. and Keller, R.T. (1999) 'The transfer and commercialization of university-developed medical imaging technology: opportunities and problems', *IEEE Transactions on Engineering Management*, Vol. 46, No. 3, pp.289–298.

Gilbert, C. (2003) 'The disruption opportunity', *MIT Sloan Management Review*, Summer, pp.22–32.

Goldscheider, R., Jarosz, J. and Mulhern, C. (2002) 'Use of the 25 per cent rule in valuing IP', *Les Nouvelles*, December, pp.123–133.

Henderson, R.M. and Clark, K.B. (1990) 'Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms', *Administrative Science Quarterly*, Vol. 35, pp.9–30.

Hill, C.W. and Rothaermel, F.T. (2003) 'The performance of incumbent firms in the face of radical technological innovation', *Academy of Management Review*, Vol. 28, No. 2, pp.257–274.

Kassicieh, S.K., Walsh, S.T., Cummings, J.C., McWhorter, P.J., Roming, A.D. and Williams, W.D. (2002) 'Factors differentiating the commercialization of disruptive and sustaining technologies', *IEEE Transactions on Engineering Management*, Vol. 49, No. 4, November, pp.375–387.

Lockett, A., Siegel, D.S., Wright, M. and Ensley, M. (2005) 'The creation of spin-off firms at public research institutions: managerial and policy implications', *Research Policy*, Vol. 34, No. 7, pp.981–993.

Lynn, G., Morone, J. and Paulson, A. (1996) 'Marketing and discontinuous innovation: the probe and learn process', *California Management Review*, Vol. 38, No. 3, pp.8–37.

Markman, G.D., Phan, P.H., Balkin, D.B. and Gianiodis, P.T. (2005) 'Entrepreneurship and university-based technology transfer', *Journal of Business Venturing*, Vol. 20, pp.241–263.

Mowery, D.C. and Shane, S. (2002) 'Introduction to the special issue on university entrepreneurship and technology transfer', *Management Science*, Vol. 48, No. 1, pp.5–9.

Muir, A.E. (1997) *The Technology Transfer System*, Latham Book Publishing, Latham, NY.

Randazzese, L.P. (1996) 'Exploring University and industry technology transfer of CAD technology', *IEEE Transactions on Engineering Management*, Vol. 43, No. 4, November, pp.393–401.

Rasmussen, E. (2006) 'Models for university technology transfer operation: patent agency and 2g', *International Journal of Technology Transfer and Commercialisation*, Vol. 5, No. 4, pp.291–307.

Reinganum, J.F. (1983) 'Uncertain innovation and the persistence of monopoly', *American Economic Review*, Vol. 73, pp.741–748.

Rice, M.P., O'Connor, G.C., Peters, L.S. and Morone, J.G. (1998) 'Managing discontinuous innovation', *Research Technology Management*, Vol. 41, No. 3, May–June, p.52.

Rogers, E.M., Yin, J. and Hoffmann, J. (2000) 'Assessing the effectiveness of technology transfer offices at US Research Universities', *Journal of the Association of University Technology Managers*, Vol. 12, pp.47–80.

Shane, S. (2002) 'Selling university technology: patterns from MIT', *Management Science*, Vol. 48, No. 1, pp.122–137.

Shane, S. and Stuart, T. (2002) 'Organizational endowments and the performance of university start-ups', *Management Science*, Vol. 48, No.1, pp.154–170.

Siegel, D.S., Waldman, D. and Link, A.N. (2003) 'Assessing the impact of organisational practices on the relative productivity of university technology transfer offices: an exploratory study', *Research Policy*, Vol. 32, No. 1, pp.27–48.

Sine, W.D., Shane, S. and Di Gregorio, D. (2003) 'The halo effect and technology licensing: the influence of institutional prestige on the licensing of university inventions', *Management Science*, Vol. 49, No. 4, pp.478–496.

Smilor, R. and Matthews, J. (2004) 'University venturing: technology transfer and commercialization in higher education', *Int. J. Technology Transfer and Commercialisation*, Vol. 3, No. 1 pp.111–128.

Thursby, J.G., Jensen, R. and Thursby, M.C. (2001) 'Objectives, characteristics and outcomes of university licensing: a survey of major US Universities', *Journal of Technology Transfer*, Vol. 26, pp.59–72.

Tushman, M.L. and Anderson, P. (1986) 'Technological discontinuities and organizational environments', *Administrative Science Quarterly*, Vol. 31, pp.439–465.

Notes

[1]We define adoption as the rate of increase in the number of new users, not simply replacing a technology with a new improved version and serving an established market, as is the case for sustaining technologies.

[2]The survey is available at: http://www.iese.uiuc.edu/pdlab/Publication.htm

[3]These universities are: University of California-Berkeley, Johns Hopkins University, Stanford University, University of Illinois-Chicago, University of Michigan-Ann Arbor, and University of California- San Diego.

[4]The amount of time it takes after licensing for a technology transfer office to recover their investment (i.e., patent cost, etc.) in that technology.

[5]Some institutions may require upfront payment of patent cost and others structure deals differently.

Website

USPTO, http://www.uspto.gov