Sustaining and Disruptive Categorization of University-Licensed Technologies: The Impact on Licensee and University Technology Revenue Stream

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Abstract

In this paper, we propose a conceptual framework which considers how the categorization 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 and/or copyrighted technologies assigned to the University of Illinois, Urbana-Champaign. Initial results indicate that sustaining technologies are most likely licensed to market leaders and most successful sustaining technologies are also licensed to market leaders. However, in contradiction to current theory, 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. As a validation measure, we circulated a survey to 12 technology transfer offices in peer institutions. We find both agreement and disagreement with our analysis from the survey results.

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

1. Introduction

Since the passage of the Bayh-Dole Act of 1980, many universities have increased their efforts and activities in technology commercialization of university-based technologies. Some of these technologies are licensed to startup 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 commercialization 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 characterization 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 categorization, 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) details key difference 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 (a) improvement in disk hard-drive capacities, (b) Improvement in resolution for photo-cameras or sensors, and (c) 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 (a) records replaced by Compact Disc, (b) Film cameras replaced by Digital Images, and (c) Inkjet vs. Laser printing.

The initial results of our study on the impact of the categorization 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 commercialization 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 commercialization. Section 3 discusses technology commercialization 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 behavior.

2. Review of University-based Technology Licensing

Numerous researchers investigate university-based technology licensing (Rasmussen, 2006). Some researchers study the impact of institutional prestige and technology licensing (Shane, 2002). These researchers note that there is 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 organization offering the technology for licensing. Others consider the impact of an organization’s endowment on the success of university start-ups (Shane and Stuart, 2002). This investigation focuses more on the social-endowment (social capital) of the organizational founders. Their results show that there is a correlation amongst the various relationships due to social networks and the impact on the success of an organization. A founder’s social network that includes venture capitalists has a better chance of obtaining financing which can impact long-term success. There is 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., 2001; Mowery and Shane, 2002; Muir, 1997; Shane and Stuart, 2002; Smilor and Matthews, 2004). Randazzese (1996) explores the technology transfer of university-based CAD technologies. He suggests that technology transfer only succeeds if the licensee firm establishes organizational incentives for the technical staff to commit time and efforts to implement university technologies. Delcampo et al. (1999) analyze the commercialization strategies for university based medical-imaging technologies. They propose that universities need to reexamine the incentive structure for investigators regarding publishing versus protecting intellectual property. Additionally, other researchers consider the overall performance of university technology transfer office in meeting their stated objectives of fostering economic development. Markman et al. (2005) state that many universities are pressured to show economic growth for the research grants given to the institution. They find that many universities see themselves as facilitators for *new venture creation* and *economic development*. Although economic development is a goal, there appears to be a paradoxical underpinning applying pressure to show return on investments in research. This investigation finds that technology offices are more and more motivated to maximize cash flows and minimize risk which leads to choices that constrain new venture creation. Lockett et al. (2005) postulate that one of the constraints on the success of spin-off firms licensing university technology is the knowledge gaps between the agents involved in the transactions. These agents include the university, inventor, spin-off organization, and the management team. They suggest that a consideration of knowledge gaps can lead to a better understanding of factors that can influence the economic performance of a spin-off organization. Siegel et al. (2003) identify a number of key environmental and organizational factors that influence the relative productivity of university technology transfer offices. Some of these factors are (1) limited resources, (2) time and effort, (3) unforced rules, (4) interest of industry, and (5) reward systems. They conclude that the most critical organizational factors are technology offices employee reward systems. Furthermore, Thursby et al. (2001) consider 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 find that the stage of development of a technology at licensing can impact future financial return to the university. They also find that there is only a marginal return as the number of technologies for a specific industry increases. They postulate on possible causes of this phenomenon, such as environmental factors.

A review of the best practices of university technology licensing offices focus on the operations, economic impact, and commercialization initiatives of the organization (Allan, 2001). One seminal paper in this area by Mowery and Shane (2002) considers the characteristics of university entrepreneurship and technology transfer. This paper focuses on four themes: (1) the relationship between university research and private sector innovation, (2) the mechanisms of technology transfer, (3) the evolution of university technology transfer activities, and (4) the creation of new firms to exploit university technology. The authors propose a series of questions regarding the types of technologies that leads to firm formation and what types are licensed to existing firms. Shane and Stuart (2002) observe 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 discuss the importance of the Bayh-Dole Act on university technology transfer. Rogers et al. (2000) discuss the types of technologies that are most frequently licensed, and quantify the overall revenue earned by university-based technologies as well as the impact on society. Boettiger and Bennett (2006) consider the overall impact of the Bayh-

Dole Act on economic development. They attempt 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 Commercialization Strategic Models

The preceding literature review has considered a breath of knowledge of research in university-based technology transfer activities and behavior. In this section, we narrow our focus, specifically, to the management and the commercialization 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) argues that a market leader is unable to effectively manage disruptive technologies. He states that disruptive technologies are not able to meet the growth demands for the organization. Christensen finds that disruptive technologies are oftentimes developed within these organizations; however, they fail to get the attention and/or resources to support commercialization. This argument is supported by Rice et al. (1998) who report that the high level of uncertainty in disruptive technologies is too much for a market leader and that disruptive innovation projects are badly aligned with the operating business reward structure. It seems that start-up organizations are better positioned to adapt to the demands of disruptive technology commercialization. Therefore, disruptive technologies are most often introduced by a start-up, and the start-up eventually overshoots the market leader within that specific technology category. Furthermore, Christensen discusses the successes of larger organizations that have spun-off these disruptive technologies into separate business units that were distanced from the culture of the larger organization. Other researchers (Abernathy and Clark, 1985; Hill and Rothaermel, 2003) show 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 explore the impact of technological changes on the organizational environment and the magnitude of these changes on the organization (Henderson and Clark, 1990; Tushman and Anderson, 1986). Lynn et al. (1996) consider techniques and methods to identify target markets for disruptive technologies. They suggest a probing and learning strategy to gain insight into which markets to pursue. Kassicieh et al. (2002) report that disruptive and sustaining technologies require different commercialization approaches and activities. If this is the case, the characterization of technologies into one of these categories could have significant impact on long-term success.

The technologies discussed by these researchers focuses on commercial industry; however, this paper specifically considers university-based technologies. As the basis of our study, we have utilized the intellectual property archive contained within the database of the Office of Technology Management (OTM) at the University of Illinois-Urbana/Champaign (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 commercialization, we propose the following two hypotheses:

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

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

Additional arguments suggest that the high level of uncertainty leads 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 organizations are not designed to successfully commercialize disruptive technologies. Christensen and Overdorf (2000) suggest that this infrastructure is entrenched in the values of the organization. To illustrate this point, they use the example that if a company's overhead cost require it to achieve gross margins of 40%, it will avoid a project that returns below 40%. Gilbert (2003) suggests that these technology disruptions are 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 recognize the threat and react successfully. These arguments lead to the following hypotheses:

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

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

Christensen (1997) suggests that disruptive technology will 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 outpaces the customer performance requirements. This phenomenon allows these disruptive technologies to eventually surpass sustaining technologies. Rice et al. (1998) state that if a firm fails to sustain their competitive edge they risk degradation of their market position. Maintaining success requires new business ventures and new products. Reinganum (1983) suggests 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 categorized as disruptive will be adopted at a faster rate and eventually supplant sustaining technologies.*[1]

We summarize the above hypotheses in the conceptual model of Figure 1. This proposed model takes as inputs technology categorization and type of licensee. The output response is identified as a measure of success (e.g. overall net income to the university). The bidirectional arrow between the *licensee* and the *technology category* suggests a hypothetical relationship between the licensee and technology categorization (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).

<INSERT FIGURE 1 ABOUT HERE>

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[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.

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 due to a lack of historical information or relevant information to the investigation. Factors stipulating exclusion from the study are: (1) No useful data within the database, (2) Information missing or not included within the database, and (3) Royalty-free agreements issued to licensee from the university.

Information on each of the technologies is archived in the Office of Technology Management (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 Return on Investment (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 cashflow by using past performance results. The transition of many university technologies to commercialization carries risk that is difficult to quantify. The methods used by the OTM are an attempt to manage this uncertainty by looking at the commercialization process holistically throughout the screening process.

Using these 135 data points, we suggest four analysis factors: (1) technology categorization, (2) success based on licensing profit, (3) licensee type, and (4) number of years since the first license was executed. The proposed model illustrates the link between technology categorization, the licensee, and the overall success (see Figure 1).

4.2 Technology Categorization

Technology categorization determines the classification of a technology as either disruptive or sustaining. In order to make this classification, we consider each technology based on two criteria: (1) is the technology an improvement or does it create a new use, and (2) 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. Based on this information along with a description of the technology and problem that the technology is attempting to solve, we would make a judgment 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. Figure 2 shows the scale assignments and descriptions for each rating.

<INSERT FIGURE 2 ABOUT HERE>

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 Figure 3.

<INSERT FIGURE 3 ABOUT HERE>

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.

4.4 Licensee Characterization

The licensee characterization 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, organization '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 organization 'X,' we will consider this as licensed to the market leader in that specific industry segment. We used a 2-point scale with values of -1 and 1. Figure 4 shows the scale assignments.

<INSERT FIGURE 4 ABOUT HERE>

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 (<10 years), we use information contained in business resource databases (e.g. One Source, Hoovers). Based on this information, we determine whether or not the organization is or is not a leader. In the case of a start-up, we took the position that if the formation of the organization was based exclusively on licensing the technology from the university, then the organization is a start-up. We use these classifications to provide an effective differentiator between the organizations used in this study.

4.5 Data Summary

Based on 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 5 shows the categorization for the disruptive technologies. Figure 6 shows the categorization for the sustaining technologies. Figure 7 shows the categorization for all the technologies.

<INSERT FIGURE 5 ABOUT HERE>

<INSERT FIGURE 6 ABOUT HERE>

<INSERT FIGURE 7 ABOUT HERE>

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 Categorization

Figures 8 and 9 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 categorized as sustaining are more likely to be licensed to market leaders*), but do not provide any conclusive evidence for Hypothesis 2 (*University-based technologies categorized 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 organization by licensing university-based technologies when possible could be a reason for this considerable percentage of licenses awarded to start-ups.

<INSERT FIGURE 8 ABOUT HERE>

<INSERT FIGURE 9 ABOUT HERE>

5.2 Analysis of Licensee and Years of Licensing for Most Successful Technologies

In considering a conditional analysis of the data, we analyze 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" categorized 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 categorized as sustaining are more successful if licensed to a market leader*), but do not provide support for Hypothesis 4 (*University-based technologies categorized as disruptive are more successful if licensed to a start-up/new venture*). Figure 10 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 maximize short-term profit and show return on research grants.

<INSERT FIGURE 10 ABOUT HERE>

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 categorized 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 suggest that disruptive technologies can 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 successfully (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 commercialized through a market leader or through a start-up.

5.4 Analysis of Technology Categorization, Years of Licensing, and Diffusion

We realize 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 analyzed in this study, the average number of years of licensing were 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. Based on 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 11 and 12 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).

<INSERT FIGURE 11 ABOUT HERE>

<INSERT FIGURE 12 ABOUT HERE>

6. Discussion and Conclusion

This investigation examines technology commercialization outcomes by considering the sustaining and disruptive nature of 135 patented or copyrighted technologies at the University of Illinois-Urbana/Champaign. Based on 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 twenty-four 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 behavior 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 are able to surpass incumbents due 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 9 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 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 nonprofit organizations, the university is motivated to offer a license to the organization even if the royalty rate is small. However, recent literature suggests that university technology transfer offices are also motivated by maximization 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: (1) only recently (< 5 years) has the University of Illinois provided assistance for startups, and (2) 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 a “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 realize that we have taken considerable liberties and assumptions in developing our conceptual model. Our hope, however, is to elucidate the potential value of categorizing university technologies along these dimensions during screening. Such categorization can provide an additional tool for university technology transfer offices in their efforts to transfer technologies out of the university.

6.1 Generalizability and Limitation of Results

One of the most significant limitations in this study is the consideration of only one institution: the University of Illinois-Urbana/Champaign. To overcome this weakness, we circulated a survey[2] to twelve peer institutions to get their feedback on the five proposed hypotheses. Six universities responded to our survey.[3] Figure 13 summarizes the categories of technologies submitted to the respondents’ technology offices. Figure 14 summarizes the percentages of respondents that agree / disagree with the hypotheses (i.e. propositions) stated in this paper and in the survey.

<INSERT FIGURE 13 ABOUT HERE>

<INSERT FIGURE 14 ABOUT HERE>

As anticipated most university technology transfer offices do not have a sustaining or disruptive categorization of their technologies during screening. However given our definition of sustaining and disruptive categorization 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 categorize as disruptive were overwhelmingly licensed to start-up firms with the

[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.

exception of some disruptive biotech and/or life sciences technologies. One respondent mentioned that due 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 due 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 University of Illinois-Urbana/Champaign 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 favoring life sciences – apparently due to the fact that they have a large medical school. This phenomenon has been investigated by other researchers (Colyvas et al., 2001; 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 organizational structure of the technology transfer office. However, we do find some literature that discusses difference and/or 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 categorization of all technologies screened by the office going forward. They plan to implement and

[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.

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 characterizations 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 organizations. However, for disruptive technologies, we observe a departure from the predicted behavior or find that the results are inconclusive.

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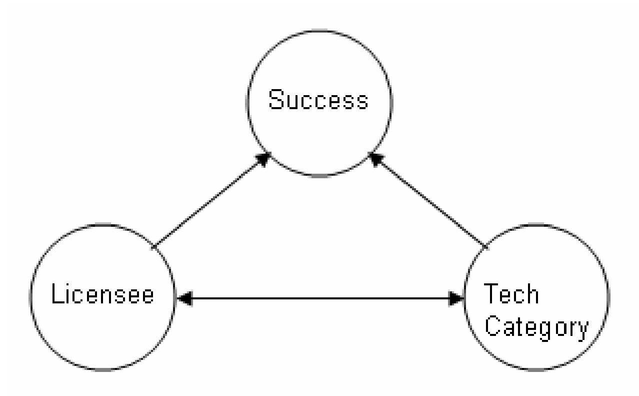

FIGURE 1: Hypothetical Model of Technology Transfer

Categorization	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

FIGURE 2: Technology Categorization Scales

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

FIGURE 3: Net Income Scale

Licensee Market Position	**Scale Rating**
Market Leader	1.0
Start-up	-1.0

FIGURE 4: Licensee Market Position Scale

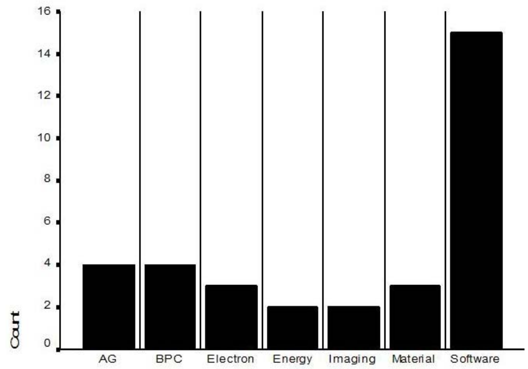

FIGURE 5: Disruptive Technologies

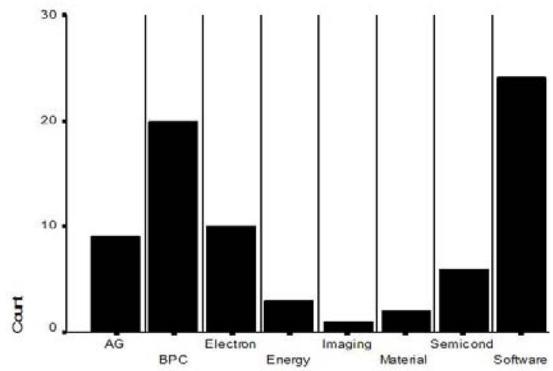

FIGURE 6: Sustaining Technologies

Legend:
- **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

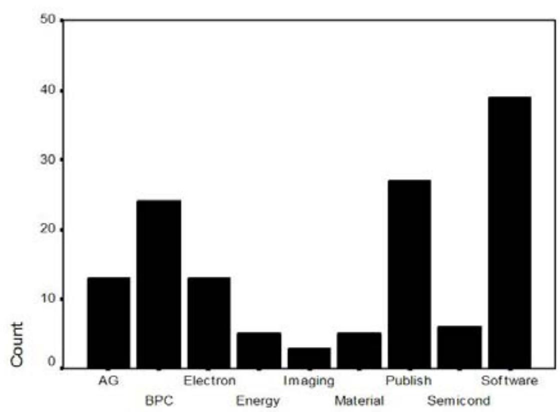

FIGURE 7: All Technology Categories

Scale Values	Frequency	Percent
-1.00	27	26.4
1.00	75	73.6
Total	102	100.0

FIGURE 8: Licensee for Sustaining Technologies

Scale Values	Frequency	Percent
-1.00	17	51.5
1.00	16	48.5
Total	33	100.0

FIGURE 9: Licensee for Disruptive Technologies

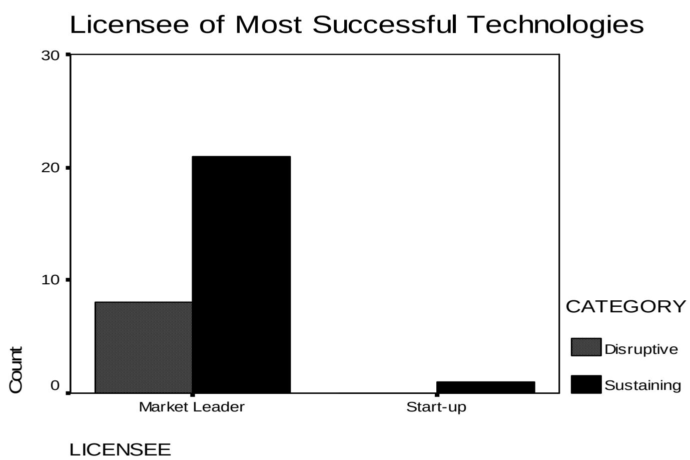

FIGURE 10: Characteristics for “Big” Winner Technologies

	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 11: Disruptive 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**

FIGURE 12: Sustaining Technologies-Hypothesis Testing

Category	% of Disclosures Submitted to Technology Transfer Office
Life Sciences	55%
Physical Science/Engineering	25%
Software	18%
Others	2%

FIGURE 13: Disclosures Allocations

	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	0.00%	83.33%	16.67%

FIGURE 14: Response to Propositions