

The Economics of University Research and Technology Transfer

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ABSTRACT

This paper presents an empirical analysis of university research and technology transfer activities. The small size of university research expenditures relative to the total R&D budget in the economy suggests that universities play a relatively minor role in applied research. By all indications, university technology transfer is expanding rapidly; however, financial results continue to lag. Universities also play a role in the transfer of knowledge to industry through sponsorship of incubators and research parks. In the past fifty years, university research has been funded primarily by federal agencies and only a small percentage by industry. With the recent turmoil in the economy and resulting shift in the government's spending priorities, the heavy reliance on government funding makes university research operations vulnerable. To survive in the long run, university research operations have to diversify their funding sources to include a larger share from industry.

I. INTRODUCTION

Following the passage of the Bayh-Dole Act in 1980, universities across the United States began to explore commercial opportunities in their inventions. Some found the business side of technology transfer incompatible with the tradition of academia. Others found insurmountable cultural disparity with corporate partners because the slow and deliberative process of the institution contrasted sharply with the rapid decision-making protocol of the business sector. Executing basic contracts on confidentiality, exclusivity, and royalty took a long time when universities demanded iron-clad provisions unacceptable to the corporate sector. A glimpse of such clashes is seen after the passage of the Bayh-Dole Act when

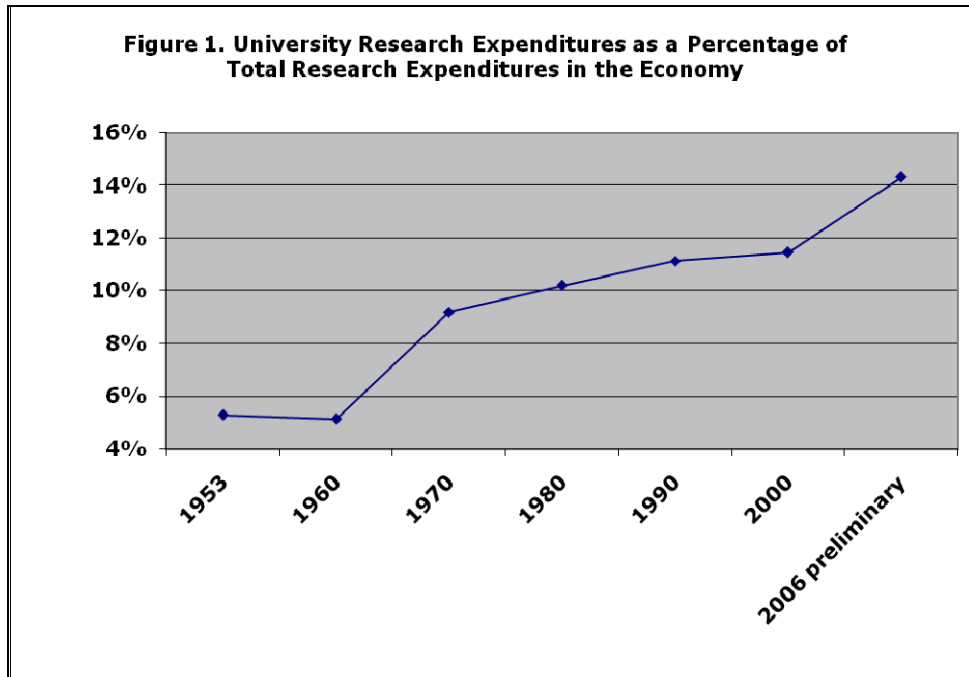
corporate support for university research initially more than doubled but quickly tapered off¹, leaving disappointed corporate entities that swore off working with the academic institutions that distrusted them.

For a large number of highly ranked research institutions, technology transfer in its most direct form remains further down on the list of priorities.² The Johns Hopkins University is one such example. It maintains a ranking of first or second in the nation in annual research expenditures but only 40th in its technology transfer enterprise.³ In general, the size of research expenditures remains a poor predictor of the extent of technology transfer activities.

In the following sections, we explore the economic theory and related empirical evidence in university research and technology transfer. In section II we investigate the structure of university research using data from the National Science Foundation (NSF). In sections III and IV we explore patterns of university patenting and licensing and the microeconomics of choice between licensing a new technology and forming a startup company around it. Sections V and VI contain an empirical investigation of the determinants of university licensing and the relationship between university research and technology transfer. In sections VII and VIII we discuss the macroeconomic factors in setting up a startup company and the critical role of venture capital firms in financing the startups and recruiting professional managers to operate them. Section IX covers knowledge flows from universities to industry through establishment of incubators and research parks; the conclusion may be found in section X.

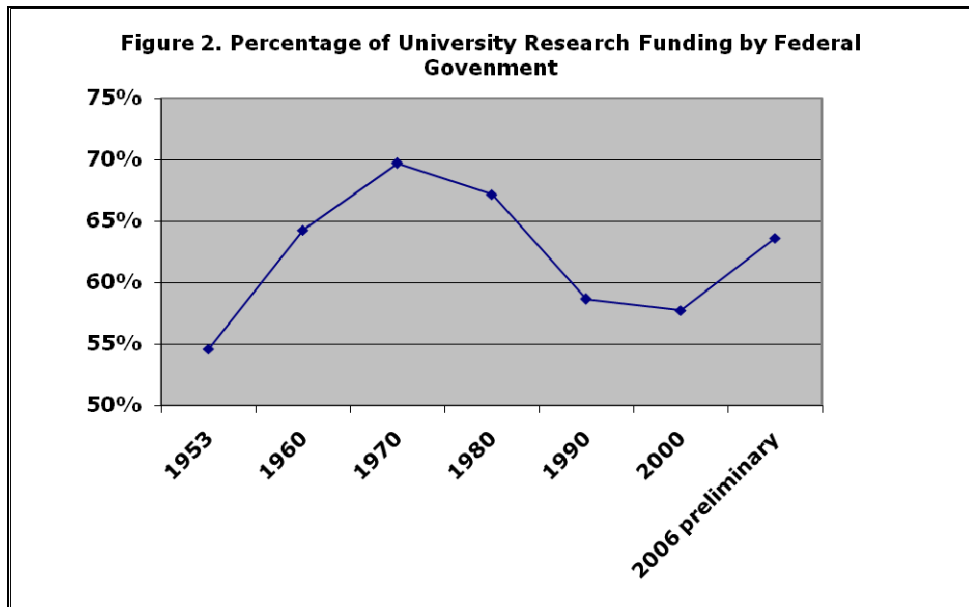
II. THE STRUCTURE OF UNIVERSITY RESEARCH FUNDING

A review of university research expenditures over the past 50 years suggests that the federal government has been the main source of research funding to both public and private universities. From 1953–2006, total research expenditures in the economy increased from \$28 billion to almost \$300 billion. During this period, university research expenditures grew by 6.5% each year from \$1.5 billion to \$43 billion.⁴ The share of university research expenditures as a percentage of total research expenditures in the economy fluctuated from 6–14% (Figure 1). Industry remained the most active, with expenditures growing at 4.5% per year from \$20 billion in 1953 (70.4% of total) to \$211 billion in 2006 (70.5% of total).⁵

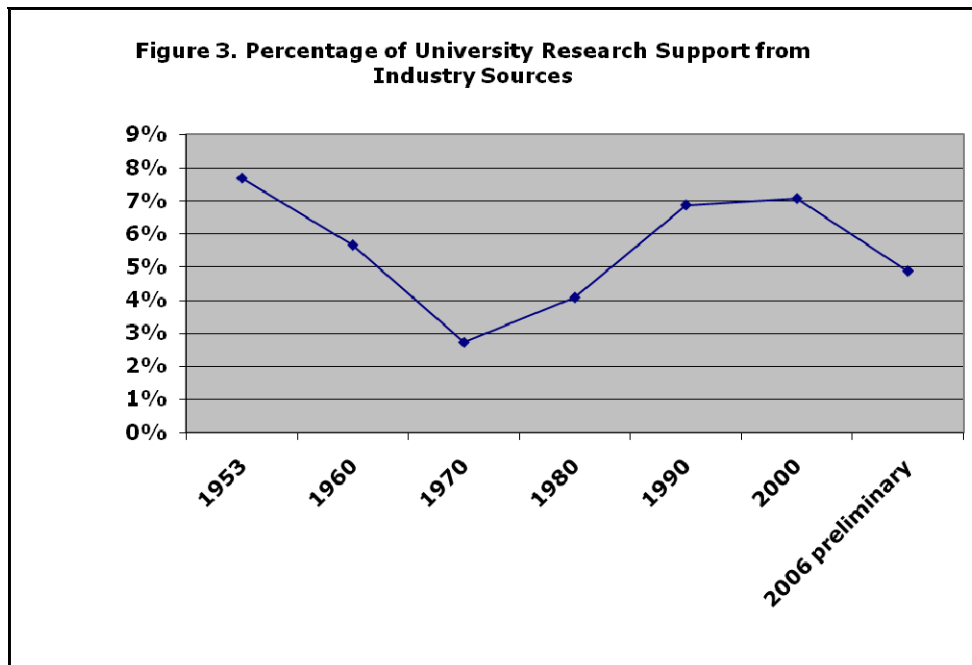


Data Source: National Science Foundation, U.S. research expenditures, by performing sector and sources of funds: 1953–2006

The share of federal government funds in university research funding ranged from 55% in 1953 to as high as 70% in 1970, declining to 64% by 2006 (Figure 2). Interestingly, the share of industry contributions to university research followed an opposite pattern. Starting at less than 8% in 1953 and falling to 3% in 1970, industry contributions increased steadily through the 1980s before stabilizing in the 1990s at 7% with a slight decline to 5% in 2006 (Figure 3). This suggests that universities behave proactively in seeking alternative sources of funding (e.g., industry) when the share of federal government funding is reduced.⁶



Data Source: National Science Foundation, U.S. research expenditures, by performing sector and sources of funds: 1953–2006



Data Source: National Science Foundation, *U.S. research expenditures, by performing sector and sources of funds: 1953–2006*

University research funding, financed primarily by the federal government, covers only a small fraction of total research in the economy.⁷ With government expenditures at historic highs coupled with declining tax revenues due to economic and financial crises, there are no guarantees that federal funding for university research is going to grow. Unless university research contributions to the total economy are significantly increased and funding sources are materially diversified, there is a real chance the quality of university research will suffer in the next fifty years. The consequences of reduced government support for universities without alternative resources are starkly evident in France. Following the student uprising in 1968, the French government reduced its support for universities, causing a steady decline in the quality of research and education. Most French universities today hardly resemble their storied past. An important alternate funding source for university research is industry. Although there always have been collaborations between the two, the current level of collaboration is relatively small.

Obstacles to productive collaborations between corporate and academic sectors go beyond differences in cultures, although such disparity is a lingering problem. There also are structural issues that need to be addressed by universities. Historically, the most common academic research setting has been an individual laboratory assigned to a faculty member that is equipped with all of the necessary instruments. Beyond generalities, research conducted in one laboratory was often unknown to other laboratories and could be duplicating not only enormously expensive instruments and infrastructure, but also ideas at great cost. Movement from this perfectly controlled, albeit inefficient, environment to a more collaborative setting is taking place gradually with encouragement from granting agencies. “The scale and complexity of today's biomedical research problems increasingly demands that scientists move beyond the confines of their own discipline and explore new organizational models for team science.”⁸

To speed up the pace of collaboration, universities should increase the availability of shared laboratory and office space equipped with an array of instruments. Shared laboratories are centrally maintained, and their upkeep can be covered at least in part by the institution’s indirect cost returns.

With shared facilities, investigators capable of performing substantive basic and applied research from multiple departments or colleges could be organized around multidisciplinary research platforms. As multidisciplinary centers grow on individual campuses, they could form material alliances with other centers in the region, state, or country, allowing them to share each other’s technology and expertise. The expected gains from such coalitions would be enormous, considering significant potential savings from economies of scale (i.e., size) and scope (i.e., joint production). With vast resources and efficient processing, these coalitions would match the industrial sector in resources, opening up opportunities for meaningful collaborations between the two. At this stage of academic consortia-industry collaborations, research programs could proceed with significant funding from both the public sector and industry.

III. UNIVERSITY PATENTING AND LICENSING ACTIVITIES

We gauge the extent of university technology transfer activities by examining a recent survey conducted by the Association of University Technology Managers (AUTM).⁹ The survey covers invention disclosures, licenses and options executed, licensing income, startups and products available to the public, among others. By all accounts, university technology transfer activities are thriving at an annual growth rate of 6%. On certain dimensions, the results show drastic annual increases, such as a 23.5% increase in the number of startups established.

The survey covers 154 universities. After deleting the observations with missing values, we ended up with 128 universities in our sample. Table 1 provides the basic statistics on the research and technology transfer activities of these institutions. The combined 2003–2005 research expenditures ranged in size from \$25 million to \$8.3 billion, with a mean of \$749 million and median of \$464 million.¹⁰

The number of startups per year ranged from 0 to 20, with a mean and median of 3 and 2, respectively. The number of licenses and options executed ranged from 0 to 265, with a mean and median of 27 and 16. The income from licenses also ranged widely, from no licensing revenues to more than \$585 million. The number of full-time equivalent (FTE) licensing agents ranged from 0 to 63, with mean and median of 5 and 3, respectively.

Table 1. Basic Statistics

2003-2005 Cumulative Research Expenditures (\$millions)		Startups	Licenses & Options Executed	Licensing Income (\$millions)	Licensing FTE
Mean	749.23	2.9	27.6	11.80	4.9
Standard Error	85.25	0.3	3.2	4.76	0.6
Median	464.45	2.0	16.0	1.52	3.0
Standard Deviation	964.45	3.5	36.5	53.80	6.4
Sample Variance	930163.02	12.0	1334.0	2894.62	41.2
Minimum	25.35	0.0	0.0	0.00	0.0
Maximum	8331.61	20.0	265.0	585.66	63.0

Data Source: AUTM, *Licensing Survey, FY2005*

IV. STARTUPS VERSUS LICENSES

In commercializing a discovery, universities face two choices: license it to an existing company, or establish a startup company around the technology. Important distinctions in the nature of discovery dictate the optimal choice.

If a discovery provides improvements over an existing technology and complements other product lines, it would make economic sense to license it to an existing company.¹¹ The new product would be incrementally better than the previous one due to higher quality, lower price, or both. For the licensor, such an arrangement provides steady royalties and little downside risk. On the other hand, if a discovery leads to a radical new technology previously unknown and enough of a platform on which to create a new company, the optimal choice for commercialization would be to establish a startup company.¹² This is predicated by the fact that a new technology is risky by nature with no existing production and distribution channels and no information on the size of the market or pricing of the product. Consequently, established companies rarely take on such high-risk inventions, especially when they are not from their own laboratories.

Despite obstacles in producing and marketing a promising technology, startups may succeed and survive if their entry into the market could potentially force existing companies with inferior technologies out of the market. However, this would be a plausible scenario only if the technology belongs to a dispersed industry with little concentration and no clear leader. In heavily concentrated sectors, developing production and sales distribution channels may be cost prohibitive.¹³

A startup company with a promising technology in a less-concentrated sector could attract angel and venture capital funds to produce and market the new technology. As the startup continues work on the new technology and successfully completes early stages of its development, established companies become interested in acquiring the startup. Alternatively, the startup may go public with help from its venture capital backers.

The FY2005 AUTM survey provides no information on the nature of the discoveries, thereby making a direct test of hypotheses based on the above discussion impossible. However, we could examine factors that affect the choice between establishing a startup, which presumably is based on the likelihood of its survival, and licensing outright to an established firm. This exercise would allow us to make inferences about the survivability of startups around new technologies.

To empirically test our contention, we use a multivariate regression model generally stated as:

$$Y_{ij} = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_j X_{ij} + \varepsilon_{ij}$$

Here, Y_{ij} represents a vector of dependent variables proxied by the annual number of startup companies established by a university, and X_{ij} represents a vector of independent variables including the number of licensing agents employed at the technology transfer office, number of U.S. patents issued annually, and amount of external research funding that explains changes in the dependent variables. β_0 is the intercept vector, and β_j is the coefficient vector for the independent variables.

Table 2 presents results of the regression analysis. The adjusted R-square is 59%, suggesting that the independent variable set explains 59% of the variability in the number of startups established. The F test

for ANOVA (analysis of variance) indicates significant differences among universities when it comes to the number of startups they form (the null hypothesis is rejected).

Table 2. Regression Analysis with Dependent Variable = Number of Startups

<i>Regression Statistics</i>						
Multiple R	0.77494					
R Square	0.60053					
Adjusted R Square	0.59087					
Standard Error	2.2193					
Observations	128					
ANOVA						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	3	918.136	306.045	62.1372	1.3639E-24	
Residual	124	610.739	4.92531			
Total	127	1528.88				
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	1.39463	0.25444	5.48113	2.3E-07	0.89101944	1.89825
Licensing FTE	-0.1459	0.07482	-1.94935	0.05351	-0.2939568	0.00224
U.S. Patents Issued	0.07505	0.01128	6.65638	8.1E-10	0.05273588	0.09737
2003–2005 Research Expenditures	0.00101	0.00053	1.89971	0.05979	-4.25E-05	0.00207

Data Source: AUTM, *Licensing Survey FY2005*

Among independent variables, the coefficient for the number of U.S. patents issued is positive and highly significant, meaning that an active patent portfolio often leads to the establishment of more startups. The coefficient for research expenditures is also positive and significant, suggesting that, on average, a large number of startups come out of highly funded research institutions. This, of course, does not mean that a university with significant research funding would automatically end up forming more startups.

The coefficient for the number of licensing agents is negative and significant. It is interesting that universities with a greater number of licensing agents end up licensing more of their inventions than setting up startups.

V. DETERMINANTS OF UNIVERSITY LICENSING ACTIVITY

We set up a regression model to investigate factors that affect the level of licenses and options executed by a group of independent variables, including the number of licensing agents, to study the impact of staffing levels on licensing outcome; cumulative research expenditures to proxy for the size of the research enterprise affecting the invention portfolio; and licensing income to test whether active licenses generate significant income. Although licenses and options signed in one year are likely to be a function of our independent variables in other years, we have used the same period for all, assuming that their magnitudes are highly correlated over time.

Table 3 presents the results. The adjusted R-square is 66%, suggesting that this group of independent variables explain 66% of the variability in the number of licenses and options executed by universities. As expected, the coefficient for the number of licensing agents is positive and highly significant, suggesting that staffing levels impact licensing activities. The coefficient for cumulative research expenditures is also positive and significant, suggesting that, on average, high levels of licensing activity are associated with large research expenditures. Interestingly, the coefficient for licensing income shows no significance, supporting the anecdotal evidence that large quantities of licenses and options signed do not automatically lead to large amounts of licensing income. Conversely, small numbers of licenses and options executed do not necessarily mean lower income. In fact, there is anecdotal evidence to suggest that universities may have differing strategies when it comes to the number of licensing contracts they sign. Some form extensive portfolios with a large number of low-paying licenses, while others focus on a few “big hits”.

Table 3. Regression Analysis—Dependent Variable = Licenses and Options Executed

<i>Regression Statistics</i>						
Multiple R	0.817001					
R Square	0.667491					
Adjusted R Square	0.659446					
Standard Error	21.31446					
Observations	128					
ANOVA						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	3	113086.701	37695.6	82.9739	1.6483E-29	
Residual	124	56333.9786	454.306			
Total	127	169420.68				
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	4.054414	2.40721767	1.68427	0.09464	-0.71014437	8.818972
Licensing FTE	2.293796	0.69789989	3.28671	0.00132	0.91245697	3.675136
20 03-2005 Research Expenditures	0.016439	0.0046254	3.554	0.00054	0.00728372	0.025594

Data Source: AUTM, *Licensing Survey FY2005*

VI. RELATIONSHIP BETWEEN RESEARCH ACTIVITY AND TECHNOLOGY TRANSFER

One would expect more technology transfer activity at universities with large research expenditures because basic research can lead to discoveries that are ultimately commercialized. Exceptions aside, we examined whether, on average, there is a relationship between research funding and the scale and scope of technology transfer activities.

To investigate this relationship, we set up a regression model with research expenditures serving as the dependent variable and number of startups established, number of licenses and options executed, amount of licensing income earned, number of licensing agents employed, and number of U.S. patents issued as independent variables. We claimed no direction for causality in our model and limited our inquiry to whether there is a relationship, regardless of the direction, between research expenditures and level of technology transfer activities.

Table 4 presents the results. The adjusted R square for the model is 86%; along with the results from the ANOVA table, we can safely say that there is a material relationship between research expenditures and certain proxies for technology transfer. Coefficients for licenses and options, number of licensing agents and U.S. patents are all significant and positive, suggesting that universities with large research expenditures are often more active in these areas. Coefficients for startups and licensing income are not significant.

Table 4. Regression Analysis: Dependent Variable = Total Research Expenditures

<i>Regression Statistics</i>						
Multiple R	0.93001					
R Square	0.86493					
Adjusted R Square	0.85939					
Standard Error	361.65					
Observations	128					
ANOVA						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	5	1E+08	2E+07	156.241	2.8E-51	
Residual	122	1.6E+07	130791			
Total	127	1.2E+08				
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	56.9022	45.9375	1.23869	0.21784	-34.036	147.84
Startups	16.1965	15.1979	1.06571	0.28866	-13.889	46.2823
Licenses & Options Executed	3.87611	1.54818	2.50365	0.01361	0.81132	6.94089
License Income in Millions	0.02227	0.61104	0.03644	0.97099	-1.1874	1.23189
Licensing FTE	81.8935	10.8155	7.5719	7.8E-12	60.4833	103.304
U.S. Patents Issued	7.00696	2.06134	3.39922	0.00091	2.92633	11.0876

Data Source: AUTM, *Licensing Survey FY2005*

Combined, these results suggest that, on average, universities with large research expenditures tend to license their technologies more often than using them to form startup companies.¹⁴ The results further suggest that large numbers of licenses and options do not necessarily lead to large amounts of licensing income. This is consistent with the anecdotal evidence that the vast majority of university technology

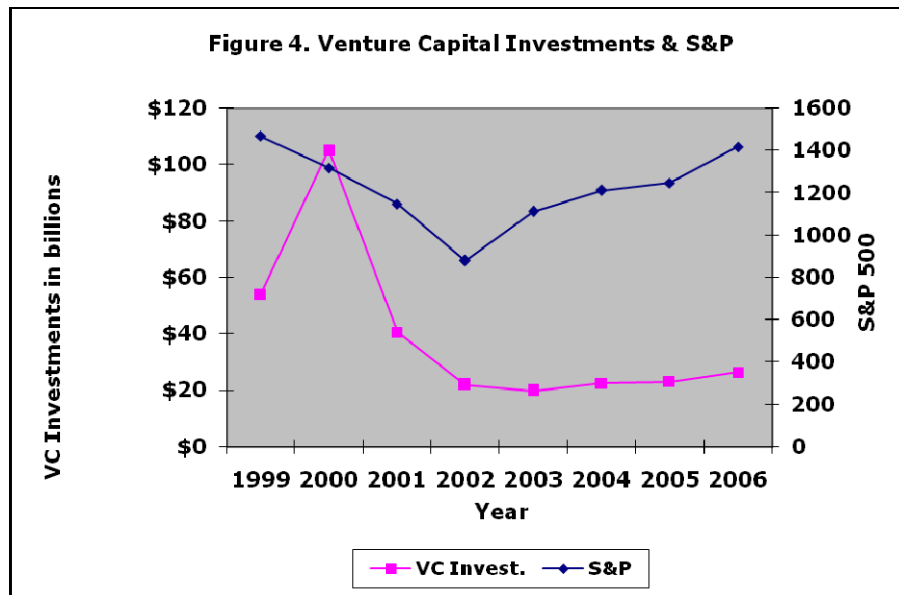
licenses produce relatively little or no income at all. Those with significant licensing income often succeed in one major discovery that leads to significant income over multiple years.

VII. MACROECONOMIC FACTORS AND STARTUP STRATEGY

In section IV we discussed the economics of setting up a startup company from the perspective of a university, suggesting that new high-risk technologies that lead to previously unavailable products may be used to establish a startup company, holding the impact of market forces constant. We address the issue of macroeconomic impact in this section.

In the early stages of development, startup companies often need significant funding from the venture capital community. The flow of venture funding is directly related to market conditions. For example, in the late 1990s and early 2000s when the stock market was at historic highs, there also was an active market for initial public offering (IPO). The prospect of taking a startup company public and divesting its investment in a timely fashion encouraged venture capital firms to invest in many deals. At their peak in 2000, venture capital firms invested \$105 billion in startups. As the market cooled shortly thereafter and the number of IPO cases declined drastically, so did the level of venture capital investments and the number of startup formations. The credit situation improved in the following years until late 2008 when a confluence of events created a serious credit crunch not only in the United States but also across the world. Although data are not currently available, the 2008 financial crisis will undoubtedly have an adverse impact on the availability of capital for startup formation.

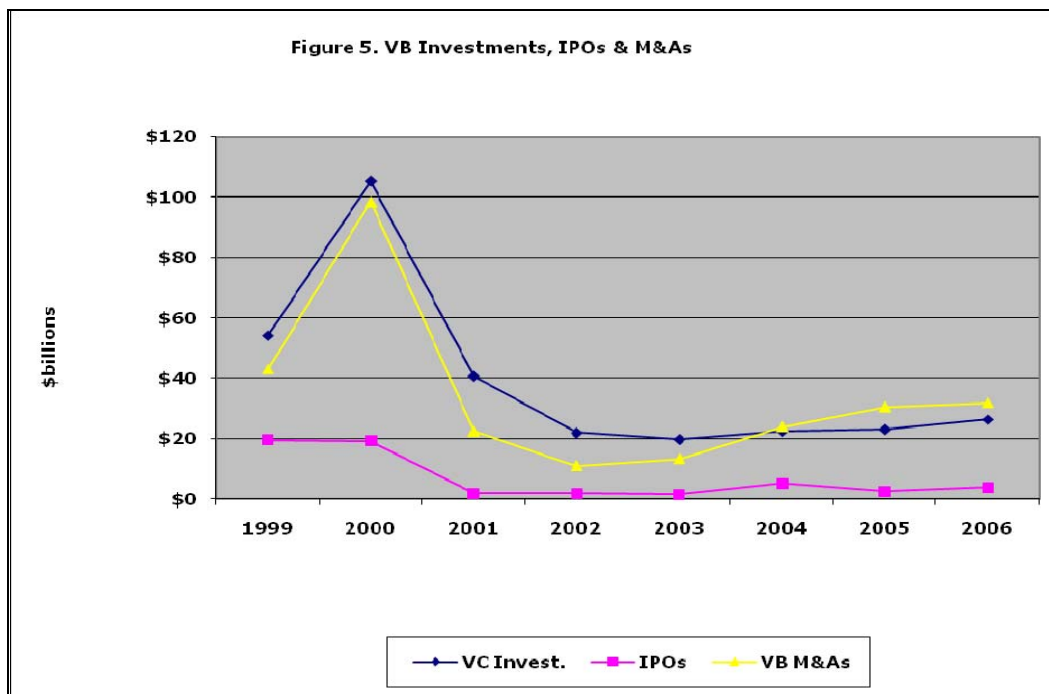
Figure 4 charts the level of venture investment and the S&P 500 index. There is a close relationship between the highs and lows of the market and the level of venture capital investments. When the stock market performs well, the market is more hospitable toward venture-backed IPOs. With prospects for a healthy IPO market, venture capital firms are more willing to make deals for startups.



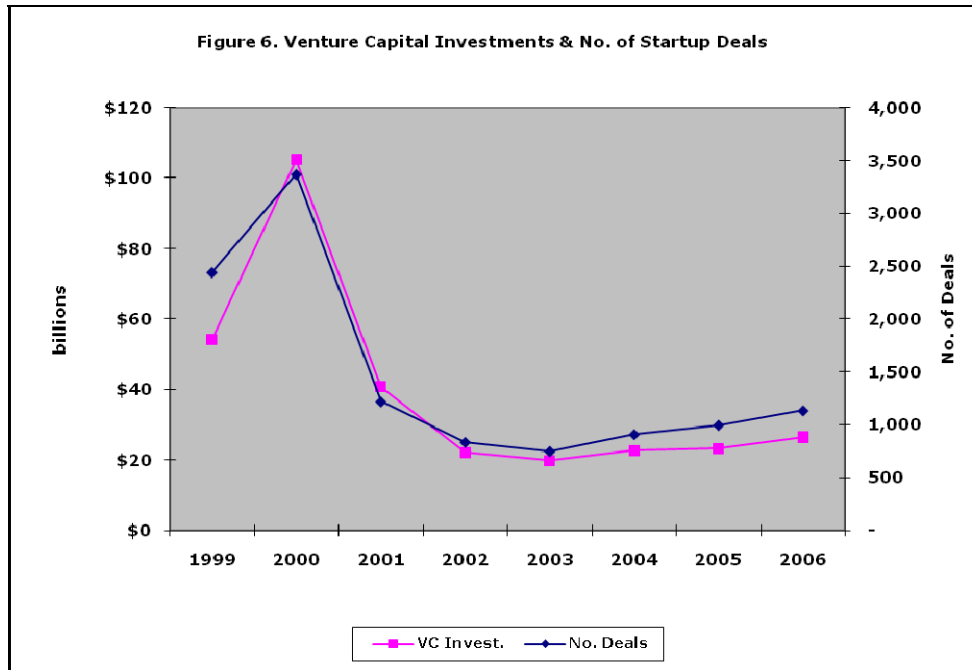
Data Source: PricewaterhouseCoopers/Thomson Venture Economics/NVCA MoneyTree™ Survey

An alternative to taking a startup public is to sell it to an existing company through mergers and acquisitions (M&As). As a startup reaches later stages of development with a clearer picture of commercial potential for its products, there is less uncertainty, and existing firms become more interested in acquiring the startup. Alternatively, a venture capital firm may want to exit from its investment in the M&A market where an established firm purchases the startup. When markets for IPOs and M&As are active and healthy, venture capital firms have clear avenues to exit from their investments.

Figure 5 presents a match-up of venture capital investments and dollars raised through venture-backed IPOs and M&As. There is a clear parallel in the dollar value of venture investments with the size of venture-backed IPO deals and venture-backed M&As. Figure 6 presents additional evidence by charting the amounts of venture investment with the number of startup deals executed. Again, there is a clear interdependent relationship between the two.



Data Source: PricewaterhouseCoopers/Thomson Venture Economics/NVCA MoneyTree™ Survey



Source: PricewaterhouseCoopers/Thomson Venture Economics/NVCA MoneyTree™ Survey

Combined, IPOs and M&As serve as the demand factor for venture assets, while investments in startups form the supply side. We contend that demand dictates supply and choice between establishing a startup company and licensing the technology to an existing entity is affected strongly by macroeconomic factors in addition to internal variables.

VIII. VENTURE CAPITAL VALUE PROPOSITION BEYOND FINANCING

In the earlier sections, we discussed the important role venture capitalists play in providing financial support for startup development. Clearly, the data show that macroeconomic factors play a major role through venture capital firms in the operation and survivability of the startups. An active equity market and the prospects of timely exit through IPOs or M&As enable the venture capitalists to engage in extensive deal-making with startups. In addition to their role as financiers, venture capital firms play an even broader and perhaps more critical role in startup management and survivability. To explore this additional function, we first examine a venture capital firm in the context of the economic theory of the “firm” and then its role as a “financial intermediary.”

There is an extensive discussion in the financial economics literature on the notion of the “firm.” The literature posits that formation of a firm is economically justified on the grounds that it creates a value-added benefit otherwise unattainable. Accordingly, a firm is defined as a nexus of contracts among investors (i.e., equity holders, bondholders, etc.) who supply the resources to acquire raw material and labor, managers who oversee the production of the output, and other stakeholders (i.e., supplier of inventory, customers of the products, etc.) toward the goal of producing certain goods or services. Since the interests of various stakeholders vary, conflicts of interest and ways to resolve them become important reasons why and how a firm is established and whether it is going to survive. For a firm to survive, it has to be economically efficient and capable of mitigating the inherent incentive problems at least as well as its competitors. Otherwise, it would be at a cost disadvantage and unable to survive in the long run.¹⁵

Similarly, in dealing with a startup company, one has to be cognizant of potential incentive conflicts among founders, who contribute the intellectual core of the business; financiers, who supply the capital; managers, who run the day-to-day operation; and other stakeholders, who come together with differing expectations. At the core, potential conflicts are due to the opaqueness of the business itself. Founders, who clearly understand the technology, often lack sufficient insights into production, sales, and other professional matters required to run a successful business. Early investors and other such stakeholders simply do not know all of the details of the technology and its prospects. And professional managers, who are recruited to handle the business side of the operation, are often uncertain whether they can make decisions based on business principles or must obtain founders' approval every step of the way.

Uncertainty engenders risk, and risk hinders the development of the firm and ultimately its value. Venture capital firms can play a crucial role in resolving the uncertainties. To understand this role, let's look at the theoretical underpinnings for financial intermediaries as a special case of firms that also include venture capitalists.

As the name suggests, financial intermediaries (e.g., commercial and investment banks, brokerage houses, insurance companies and venture capital firms, among others), stand between individual lenders, who would like to invest in an enterprise with promising returns but are reluctant to do so because of significant information disparity, and ultimate borrowers, who intentionally or unintentionally keep the details of their businesses secret. Enter financial intermediaries that could, on behalf of the investors, perform all of the necessary due diligence through extensive information-gathering, sorting, and analysis before making an investment decision. So goes the modern theory of financial intermediation that assigns a unique role to the intermediaries due to their ability to produce the necessary information and mitigate the information asymmetry problem between ultimate borrowers and lenders.¹⁶

This unique role allows the intermediaries to collect non-public information about the borrowers (i.e., startups) and keep it confidential. It is the promise of confidentiality that convinces the startup to voluntarily release its technology secrets in return for a substantial investment by the intermediary. Since the intermediary becomes an equity holder or "residual claimant," the interests of the startup founders and the intermediaries are aligned such that both would profit if trade secrets are kept from competitors over the period of time necessary for development of the technology and building of the infrastructure before entering the market. As financial intermediaries, venture capital firms engage in confidential information-gathering and processing about a startup before making an investment decision.

In addition, venture capital firms may go further than any other intermediaries by exerting varying levels of influence in the day-to-day operations of a startup. This unique role among intermediaries is afforded to venture capital firms because, unlike other intermediaries that provide loans but remain outside the firm (e.g., commercial banks), venture capital firms often become active in the management of the startup in varying degrees, from joining the board to helping to establish a professional management team.

Venture capital firms play either a "soft role" or a "hard role" in dealing with the management of a startup. The former entails steps that are considered "accommodating" to founders, whereas the latter is characterized as "separating."¹⁷ An example of such an intervention is seen in hiring outside CEOs. On occasion, founders agree to change their role and remain in the firm as CTO or VP for Development. These cases are indicative of a "soft role" that venture capital firms play. You may also see this in cases in which founders decide to move to other projects outside the startup but remain on the board. When a new CEO is recruited and thereafter the founders break all connections to the company, it is highly likely that the venture capital role in the changeover is of the "hard" kind. In a survey of 91 turnovers in Silicon

Valley startups, 38 cases (40%) were reported as soft and accommodating.¹⁸ If this is the trend, one could conclude that changeovers are often accompanied by separation from original founders and the startup.

In addition to their role in hiring CEOs, venture capital firms often put in place professional management teams that also take care of production, sales, marketing and human resources functions. Such interventions, by all accounts, are positive and help the survivability of the startups.

IX. UNIVERSITY KNOWLEDGE FLOW AND ECONOMICS OF UNIVERSITY-BACKED INCUBATORS

In this section, we go beyond the mere size of university research expenditures as a gauge of its significance and explore other, albeit indirect, avenues through which universities contribute to the economy. One such category of contributions includes university-backed incubators and research parks. By all accounts, these entities provide unique contributions to the economy but their significance has been difficult to measure beyond anecdotes.

A related issue is the impact of university research on total research in the economy. University research results are extensively, freely, and publicly disseminated through publications, conferences, consulting contracts, joint ventures, and patents. Access to such extensive sources of advanced information is vital for industry research.

Early research in this field, especially that focusing on the overall impact of university research on industry, uniformly supports the view that universities play a crucial role in the success of industry research. For example, studies have shown that academic research, measured by publications, contributed to 18 of 20 two-digit U.S. manufacturing industries over a 40-year period beginning in 1943.¹⁹ Others have shown that university research has made significant contributions to future generations of industrial patents.²⁰

Two influential surveys—the 1983 Yale Survey and 1994 Carnegie Mellon Survey of R&D managers—inquied about the relevance of university research for technical progress in industry. The results strongly supported the notion that university research has had a major impact on the scientific development of the industry, especially in the drug, chemical, and electronics fields.²¹

University-backed incubators provide an opportunity to directly test knowledge flows from university research to incubator companies. A study investigated whether knowledge flows enhance incubator firm performance using firm-level data for 79 companies incubated between 1998 and 2003 in the Advanced Technology Development Center, an incubator sponsored by the Georgia Institute of Technology.²² University knowledge flows were identified through licenses to the resident companies, company patent citations of university research, and research by the incubator-sponsoring university and non-sponsoring universities. The study gauged incubator-resident performance by company revenues, total external funding, and venture capital investments, and whether the company graduated from the incubator in a timely manner. The results revealed no significance for the revenue variable (most likely due to age of the firm), but a positive correlation between university knowledge flows and other aspects of performance such as venture capital investments and timely graduation. Interestingly, holding sponsoring-university licenses did not affect resident performance per se, suggesting that once an incubator is set up, it really does not matter whether companies that reside in the facilities are spin-offs from the sponsoring university or non-sponsoring universities.

With more than 4,500 incubators worldwide, including 1,500 university-sponsored operations, startup companies and their natural habitats, incubators, have become important players in the business of commercializing discoveries. Add the impact of university research parks, which house medium and large companies, and universities play a major role in the commercialization of new discoveries and in economic development.²³ This impact is disproportionate to the relative small size of university research expenditures. Finally, studies show that proximity to a university is a good predictor of an incubator, resident company, and research park performance.²⁴ Despite advances in telecommunication technology, which is supposed to make geography and distance less relevant in conducting research or attending the business of an enterprise, proximity to university researchers and other expertise on campus is a crucial factor in the performance of incubator startup companies and research parks.

X. CONCLUSIONS

This paper is a data-driven inquiry into the current status and future direction of university research and technology transfer. Our results show that university research expenditures, funded primarily by federal agencies, constitute a small fraction of the total R&D budget in the economy. Furthermore, the percentage of university research funded by industry is in the single digits. However, this does not negate the fact that the flow of basic research knowledge to industry remains high. Our results further indicate that technology transfer activities have grown unevenly across universities. Interestingly, the size of research expenditures turns out to be a necessary but insufficient condition for the level of tech transfer activities; and the size of licensing revenues does not seem to correlate with the number of licenses and options issued. University-sponsored incubators and research parks contribute significantly to the success of startup companies by virtue of the flow of new knowledge through licensing and other forms of collaborations. Recent turmoil in the economy has put university research and related technology transfer activities at risk. To survive in the long run, university research operations have to diversify their funding sources to include a larger share from industry.

ENDNOTES

1. National Science Foundation, *U.S. Research and Development Expenditures*, various issues.
2. In addition to direct transfer of technology, there are other ways to get the results of research out to the public domain. For example, publishing research results helps corporate R&D departments in developing commercial products.
3. This ranking may change as Johns Hopkins moves aggressively into the technology transfer field assisted by its new Carey Business School opened on January 1, 2007.
4. National Science Foundation, *U.S. Research and Development Expenditures*, various issues.
5. All in 2000 constant dollars.
6. Other sources of research funding for universities include state governments and not-for-profit foundations.
7. When we compare university and industry research, our focus is on applied research. Historically, universities have been minor players in applied research while focusing primarily on basic research. The contribution of basic research to industrial R&D is significant.

8. NIH, *Roadmap for Medical Research*.

9. Association of University Technology Managers (AUTM), *U.S. Licensing Survey: FY 2005*.

10. The \$8.3 billion figure was for the University of California System. Johns Hopkins, with \$4.73 billion, was the largest single university. See http://www.autm.net/pdfs/AUTM_LS_05_US.pdf.

11. In concentrated industries existing firms often have extensive sales and distribution channels unavailable to a new startup. In these cases, there is a compelling argument for licensing. See Teece (1986). For a broader argument on concentrated industries requiring large sums of asset-specific investments in production and marketing channels, see Williamson (1985).

12. Prior research in this area is extensive. Most focus on the survivability of startup companies. To the extent survivability depends on the same set of factors that dictate the choice of organizing a startup instead of licensing the IP, its outcome could be parallel to ours. See, for example, Tushman and Anderson (1986), Henderson (1993), Lerner (1994), Utterback (1994) and Christensen and Bower (1996). A more direct argument linking survivability to exploitation of radical technologies with broad scope patents is made by Shane (2001).

13. For a theoretical and empirical implication of this argument, see Nerkar and Shane (2003).

14. Another explanation could be that in some cases universities do not directly get involved in forming companies; instead, the entrepreneurial faculty initiate forming startups and then request tech transfer offices to license the intellectual property to such companies.

15. Coase (1937) discussed the firm and many economic issues surrounding its optimal structure. Later, Jensen and Meckling (1976) and Williamson (1985) expanded on the topic. For a detailed survey of the field, especially in the context of financial firms, see Arshadi and Karels (1997), "Why Do Firms Exist?" (chapter 2).

16. For a survey of the unique role for financial intermediaries, see Arshadi and Karels (1997), "Why Do Financial Intermediaries Exist?" (chapter 3).

17. Hellmann and Puri (2002) use these terms to differentiate between an intervention that is welcomed by the founders, therefore termed "soft," and the kind considered coercive, which is termed "hard."

18. Hellmann and Puri (2002).

19. See Adams (1990). There was, however, a major lag time up to ten years for applied sciences and engineering and up to twenty years for basic science publications.

20. Jaffe (1979).

21. See Klevorick et al. (1994) and Cohen et al. (1998).

22. See Rothaermel and Thursby (2005).

23. As an example, UM-St. Louis, a Carnegie-classified "high research activity" institution, is the founder of two incubators (Center for Emerging Technologies and IT Enterprises) and a research park. The two incubators combined provide 150,000 square feet of space to startups in biotech and IT. The research park

sits on approximately 100 acres of land with Express Scripts, Inc., a Fortune 150 company, as its anchor tenant.

24. Link and Scott (2004).

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