University Entrepreneurship and Economic Growth

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Abstract

Much of the literature examining the impact of the Bayh-Dole Act has been based on the impact on patenting and licensing activities emanating from offices of technology transfer. Studies based on data generated by offices of technology transfer, suggest a paucity of entrepreneurial activity from university scientists in the form on new startups. There are, however, compelling reasons to suspect that the TTO generated data may not measure all, or even most of scientist entrepreneurship. Rather than relying on measures of scientist entrepreneurship reported by the TTO and compiled by AUTM, this study instead develops alternative measures based on the commercialization activities reported by scientists. In particular, the purpose of this paper is to provide a measure of scientist entrepreneurship and identify which factors are conducive to scientist entrepreneurship and which factors inhibit scientist entrepreneurship. We do this by developing a new database measuring the propensity of scientists funded by grants from the National Cancer Institute (NCI) to commercialize their research as well as the mode of commercialization. We then subject this new university scientist-based data set to empirical scrutiny to ascertain which factors influence both the propensity for scientists to become an entrepreneur. The results suggest that scientist entrepreneurship may be considerably more robust than has generally been indicated in studies based on TTO data.

1. Introduction

The enormous investment in physical plant and equipment propelled the United States to unprecedented post World War II prosperity. In the new era of globalization, both scholars and policy makers have been looking towards the country's unrivaled investment in research and knowledge to generate economic growth, employment and competitiveness in internationally linked markets for continued prosperity. However, it has been long recognized that investment in scientific knowledge and research alone will not automatically generate growth and prosperity. Rather, these new knowledge investments must penetrate what has been termed "*the knowledge filter*" in order to contribute to innovation, competitiveness and ultimately economic growth. In fact, the knowledge filter impeding the commercialization of investments in research and knowledge can be formidable. As Senator Birch Bayh warned, "A wealth of scientific talent at American colleges and universities — talent responsible for the development of numerous innovative scientific breakthroughs each year — is going to waste as a result of bureaucratic red tape and illogical government regulations…"[1] It is the knowledge filter that stands between investment in research on the one hand, and its commercialization through innovation, leading ultimately to economic growth, on the other.

Seen through the eyes of Senator Bayh, the magnitude of the knowledge filter is daunting, "What sense does it make to spend billions of dollars each year on government-

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[1] Introductory statement of Birch Bayh, September 13, 1978, cited from the Association of University Technology Managers Report (AUTM) (2004, p. 5).

supported research and then prevent new developments from benefiting the American people because of dumb bureaucratic red tape?"[2]

In an effort to penetrate such a formidable knowledge filter, the Congress enacted the Bayh-Dole Act in 1980 to spur the transfer of technology from university research to commercialization.[3] The goal of the Bayh-Dole Act was to facilitate the commercialization of university science. Assessments about the impact of the Bayh-Dole Act on penetrating the knowledge filter and facilitating the commercialization of university research have bordered on the euphoric,[4] "Possibly the most inspired piece of legislation to be enacted in America over the past half-century was the Bayh-Dole Act of 1980. Together with amendments in 1984 and augmentation in 1986, this unlocked all the inventions and discoveries that had been made in laboratories through the United States with the help of taxpayers' money. More than anything, this single policy measure helped to reverse America's precipitous slide into industrial irrelevance. Before Bayh-Dole, the fruits of research supported by government agencies had gone strictly to the federal government. Nobody could exploit such research without tedious negotiations with a federal agency concerned. Worse, companies found it nearly impossible to acquire exclusive rights to a government owned patent. And without that, few firms were willing

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[2] Statement by Birch Bayh, April 13, 1980, on the approval of S. 414 (Bayh-Dole) by the U.S. Senate on a 91-4 vote, cited from (AUTM) (2004, p. 16).

[3] Public Law 98-620

[4] Mowery (2005, p. 40-41) argues that such a positive assessment of the impact on Bayh-Dole is exaggerated, "Although it seems clear that the criticism of high-technology startups that was widespread during the period of pessimism over U.S. competitiveness was overstated, the recent focus on patenting and licensing as the essential ingredient in university-industry collaboration and knowledge transfer may be no less exaggerated. The emphasis on the Bayh-Dole Act as a catalyst to these interactions also seems somewhat misplaced."

to invest millions more of their own money to turn a basic research idea into a marketable product."[5]

An even more enthusiastic assessment suggested that, "The Bayh-Dole Act turned out to be the Viagra for campus innovation. Universities that would previously have let their intellectual property lie fallow began filing for – and getting patents at unprecedented rates. Coupled with other legal, economic and political developments that also spurred patenting and licensing, the results seems nothing less than a major boom to national economic growth."[6]

The mechanism or instrument attributed to facilitating the commercialization of university scientist research has been the university Technology Transfer Office (TTO). While the TTO was not an invention of the Bayh-Dole Act, its prevalence exploded following passage of the Act in 1980. Not only does the TTO typically engage in painstaking collection of the intellectual property disclosed by scientists to the university but also the extent of commercialization emanating from the TTO. The Association of University Technology Managers (AUTM) collects and reports a number of measures reflecting the intellectual property and commercialization of its member universities. A voluminous and growing body of research has emerged documenting the impact of TTOs on the commercialization of university research. Most of these studies focus on various measures associated with university TTOs (Shane, 2004, Powers and McDougal 2005, Siegel and Phan, 2005; Di Gregorio and Shane, 2003, Mowery, 2005.) By most accounts, the impact on facilitating the commercialization of university science research has been impressive.

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[5] "Innovation's Golden Goose," *The Economist*, 12 December, 2002.

[6] Cited in Mowery (2005, p. 64)

However, in terms of scientist entrepreneurship, measured by new ventures started by university scientists, the data reported by university TTOs and collected by AUTM suggests a paucity of commercialization spilling over from universities. In the first years of this century, which also pre-dated the financial and economic crises, the number of startups emanating from U.S. universities reported by AUTM averaged 426 per year from 1998 to 2004. Given the magnitude of research budgets and investments in knowledge at American universities, an estimated total between 1998 and 2004 funded by the United States government granting agencies, this measure of university startups is both startling and disappointing.

Similarly, O'Shea *et al*. (2008) report that, for all its research prowess and headlines as an engine of the Route 128 high tech entrepreneurial cluster around Boston (Saxenien, 1994), the technology transfer office at MIT registered only 29 startups emanating from the university in 2001. Its counterpart, which is generally considered to have fuelled the Silicon Valley high-tech cluster (Saxenien, 1994), Stanford University, registered just 6 startups. Based on the TTO data measuring scientist entrepreneurship at universities compiled by AUTM, the Bayh-Dole does not seem to have had much of an impact on the economy.

However, there are compelling reasons to suspect that measuring and analyzing the commercialization of university research by relying solely upon data collected by the TTOs *may lead to a systematic underestimation of commercialization and innovation emanating from university research*. The mandate of the TTO is not to measure and document all of the intellectual property created by university research along with the subsequent commercialization. Rather, what is measured and documented is the intellectual property and commercialization activities with which the TTO is involved. This involvement is typically a subset of the broader and more pervasive intellectual property being generated by university research and its commercialization which may or may not involve the TTO office (Thursby and Thursby, 2005). For example, in his exhaustive study on academic spinoffs, Shane (2004, p. 4) warns, “Sometimes patents, copyrights and other legal mechanisms are used to protect the intellectual property that leads to spinoffs, while at other times the intellectual property that leads to a spinoff company formation takes the form of know how or trade secrets. Moreover, sometimes entrepreneurs create university spinoffs by licensing university inventions, while at other times the spinoffs are created without the intellectual property being formally licensed from the institution in which it was created. These distinctions are important for two reasons. First it is harder for researchers to measure the formation of spinoff companies created to exploit intellectual property that is not protected by legal mechanisms or that has not been disclosed by inventors to university administrators. As a result, this book likely underestimates the spin-off activity that occurs to exploit inventions that are neither patented nor protected by copyrights. This book also underestimates the spin-off activity that occurs “through the back door”, that is companies founded to exploit technologies that investors fail to disclose to university administrators.”

There is little empirical evidence supporting Shane’s (2004) admonition that relying solely upon the data registered with and collected by the TTO will result in a systematic underestimation of commercialization and ownership of university research(Thursby et al., 2009, and Aldridge and Audretsch, 2010). Such an underestimation of commercialization of university research may lead to an underestimation of the impact that spillovers accruing from investment in university research have on innovation and ultimately economic growth.

If the spillover of knowledge generated by university research is viewed as essential for economic growth, employment creation, and international competitiveness in global markets, the systematic underreporting of university spillovers resulting from the commercialization of scientist research concomitantly may lead to severe policy distortions. Thus, rather than relying on measures of scientist entrepreneurship reported by the TTO and compiled by AUTM, this study instead develops alternative measures based on the commercialization activities reported by scientists. In particular, the purpose of this paper is to provide a measure of scientist commercialization of university research and identify which factors are conducive to scientist entrepreneurship and which factors inhibit scientist entrepreneurship. We do this by developing a new database measuring the propensity of scientists funded by grants from the National Cancer Institute (NCI) to commercialize their research as well as the mode of commercialization. We then subject this new university scientist-based data set to empirical scrutiny to ascertain which factors influence the propensity for scientists to become an entrepreneur.

The second section of the paper develops the main hypotheses about why some universities engage in entrepreneurship while others abstain from entrepreneurial activities. In the third section the data base for university scientists funded by the National Cancer Institute of the National Institutes of Health (NIH) is explained. The hypotheses for scientist entrepreneurship are tested in the fourth section and the results presented. Finally, a summary and conclusions are presented in the last section. In particular, by asking scientists what they do rather than the university technology transfer offices, this paper finds that the Bayh-Dole Act has resulted in a strikingly robust and vigorous amount of scientific entrepreneurship. We find that one-quarter of patenting scientists have commercialized their research by starting a firm.

2. The Scientist Entrepreneurial Decision

A compelling literature has developed, both theoretically, as well as being substantiated with robust empirical evidence, explaining why some people choose to become an entrepreneur, in the form of starting a new firm, while others do not (Parker, 2010). However, a review of Parker's comprehensive and exhaustive review of the literature reveals that virtually none of these studies have focused on the decision by university scientists to become an entrepreneur. What is known about entrepreneurial scientist startups originating from universities has normally been inferred from data where the unit of analysis was the university..

Thus, the starting point for analyzing the decision by scientists to become an entrepreneur is the extensive literature on the entrepreneurial choice for the context of a broad population. To this we will add specific considerations for the scientist context. Four types of factors have been found to shape the individual decision to become an entrepreneur – characteristics specific to the individual, human capital, social capital, and access to financial capital. The personal characteristics found to influence the decision to become an entrepreneur for the context of the general population include the age and gender of the individual. The human capital of the individual, typically measured in terms of years of education, has been found to have a positive impact on the decision to become an entrepreneur.

Social capital refers to meaningful interactions and linkages the scientist has with others. While *physical capital* refers to the importance of machines and tools as a factor of production

(Solow, 1956), the endogenous growth theory (Romer 1986, 1990; Lucas 1988) puts the emphasis on the process of knowledge accumulation, and hence the creation of *knowledge capital*. The concept of *social capital* (Putnam, 1993 and Coleman, 1988) can be considered a further extension because it adds a social component to those factors shaping economic growth and prosperity. According to Putnam (2000, p.19),"Whereas physical capital refers to physical objects and human capital refers to the properties of individuals, social capital refers to connections among individuals – social networks. By analogy with notions of physical capital and human capital – tools and training that enhance individual productivity – social capital refers to features of social organization, such as networks that facilitate coordination and cooperation for mutual benefits."

Similarly, social capital is considered by Coleman (1988) to be "a variety of entities with two elements in common: they all consist of some aspect of social structure, and they facilitate certain actions of actors...within the structure." A large and robust literature has emerged attempting to link social capital to entrepreneurship (Aldrich and Martinez, 2003, Shane, 2002, and Thorton and Flynn, 2003). According to this literature, entrepreneurial activity should be enhanced where investments in social capital are greater. Interactions and linkages, such as working together with industry, are posited as conduits not just of knowledge spillovers but also for the demonstration effect providing a flow of information across scientists about how scientific research can be commercialized (Thursby and Thursby, 2004).

While the general literature on entrepreneurship provides a starting point for analyzing the entrepreneurial decision confronting scientists, there are additional considerations that are special or unique to the scientist context. One of these is the role played by the technology transfer office. Studies provide evidence that offices of technology transfer are not homogeneous across universities and are likely to impact scientific entrepreneurship in different ways. As shown, in table one, Markman *et al*. (2005) illustrate how mission statements of 128 university TTOs show a vast majority place emphasis in licensing over scientist startups and economic development.

Similarly, O'Shea, Allen, Chevalier and Roche (2005), and Lockett and Wright (2005) show that characteristics of the TTO influence the propensity for scientists to become an entrepreneur.

Thus, as the general literature suggests, the propensity of a scientist to become an entrepreneur is expected to be influenced by individual characteristics, such as age and gender, human capital, social capital and financial capital, but in addition, characteristics of the technology transfer office.

3.Measurement

While AUTM collects and makes available data identifying TTO sponsored and approved scientist startups, the data are aggregated at the level of the university TTO. In fact, no large-scale, systematic data base measuring scientist entrepreneurship for the disaggregated level of the individual scientist exists.

Thus, in order to analyze scientist entrepreneurship at the level of the individual scientist, rather than at the level of the aggregated university TTO, we had to create a unique and new data base. The starting point for creating a data base measuring the entrepreneurial activity, in terms of scientist startups, was to identify those scientists awarded a research grant by the National Cancer Institute between 1998 and 2002. Of those research grant awards, the largest twenty percent, which corresponded to 1,693 scientist awardees, were taken to form the database used in this study. The National Cancer Institute (NCI) awarded a total of $5,350,977,742 to the 1,693 highest funded quintile of United States-based scientists from 1998 to 2002.

The second step in creating the scientist entrepreneurship data base was to identify which of the scientists receiving funding to support basic research from The National Cancer Institute subsequently received patent protection for an invention. This suggested a sub-set of scientists receiving support for basic research that had potential commercialization applications. NCI award scientists being granted a patent was identified by obtaining patent data from the United States Patent and Trademark Office (USPTO).

To match the patent records with the 1,692 NCI recipient scientists, Structured Query Language (SQL) and Python programming languages were written to extract and manipulate data. A match between the patentee and NCI awardee databases was considered to be positive if all four of the following necessary conditions were met:

The first necessary condition was that a positive match was made with the first, middle, and last name. If, for example, the scientist did not have a middle name listed on either the NCI award database or the patent database, but did have a positive first and last name, this first condition was considered to be fulfilled.

The second criterion involved matching the relevant time periods between the two databases. Observations from both databases were matched over the time period 1998-2004, which corresponds to the initial year in which observations were available from the NCI database (1998-2002) and the final year in which patents were recorded in the patent database (1975-2004). Because applications of patents may take anywhere from three months to two years to be issued, the 2003 and 2004 USPTO patent records were included in our query. Issued patents from 1998 to 2004 by NCI scientists fulfilled the second criterion.

The third criterion was based on location. If the patentee resided within an approximate radius of 60 miles from the geographic location of the university, the third condition was fulfilled. The fourth criterion was based on USPTO patent classification. Using the USPTO patent classification code, all patents were separated into respective coding groups. Patents which did not fall under the traditional categories of biotechnology were identified. All non biotech patents were evaluated and patents such as “Bread Alfalfa Enhancer” were rejected as an NCI scientist. Based on these four match criteria, a subset of 398 distinctly issued patentees were identified between 1998 and 2004 with a total of 1,204 patents.

While the patent records identify which of the NCI Award scientists have been awarded a patent to protect the intellectual property representing an invention, they provide no indication whether or not the scientist has started a business. To identify whether a scientist had started a firm, we implemented a survey of the NCI scientists with a patent. The survey instrument was designed with two main criteria. The first was to maximize information without overly burdening the nation’s top medical scientists. Reducing the time and input burden imposed on the scientist was considered to have a favorable impact on the response rate. The second was to maximize information revealing the creation of intellectual property and its subsequent commercialization through licensing and entrepreneurial activity, while at the same time respecting the need for scientist confidentiality and not confronting the scientist with information requests that might compromise such confidentiality.

Based on these two criteria, an interview instrument was designed probing four subgroups of issues: licensing, entrepreneurship, social capital and the role of the TTO. The question in the licensing section asked if the scientist has licensed their intellectual property. The question contained in the entrepreneurship section identified whether the scientist started a new firm. The questions concerning social capital asked the scientist if she sat on any industry science advisory boards (SAB) or board of directors, the extent to which the NCI grant award facilitated commercialization, along with other sources of major funding received from a governmental agency. The questions concerning the influence of the TTO asked whether the university's TTO "directly helped you to commercialize your research between 1998 to 2004".

The 398 patenting scientists were "Googled" to obtain their e-mail and telephone information. The records could, generally, be found by typing their full name, university and the word "oncology". The ensuing patentee e-mail accounts and telephone numbers were then collected and registered in the scientist database. Of those 398 scientists identified in the database, 146 responded. Six respondents indicated that they had not patented the ascribed patents, therefore reducing the number of patentees to 392. The number of respondent, therefore, reflects a response rate of 36 percent. Of these respondents, one in four reported that they had, in fact, started a firm. This is a strikingly high degree of entrepreneurial activity exhibited by these high profile scientists, and certainly reflects a much more robust and extensive degree of entrepreneurship than has been indicated by the TTO data collected by AUTM.

Section two identified from the literature five different types of factors shaping the decision by a scientist to become an entrepreneur – personal characteristics, human capital, social capital, financial resources, and TTO characteristics. These factors are empirically operationalized through the following measures:

Personal Characteristics:

Two measures reflecting the personal characteristics of scientists are included. The first is the age of the scientist, measured in terms of years, which was obtained from the scientist survey. The life cycle hypothesis of Stephan and Levin (1991) suggests a positive coefficient, which would reflect a higher propensity for more mature scientists to engage in commercialization activities, such as entrepreneurship.

The second measure is gender. This is a dummy variable assigned the value of one for males (1,310) of the overall 1,693 included in the NCI database. The gender of each scientist was obtained by "Googling" their names, i.e pictures. The estimated coefficient will reflect whether the gender of the scientist influences the propensity to commercialize research.

Scientist Human Capital

A unique computer program was used to measure scientist citations over the period 1998 – 2004, using the "Expanded Science Citation Index." Higher levels of human capital were inferred by a greater citation count divided by the number of publications. This measure has been used elsewhere to reflect the human capital of scientists. A positive relationship is expected to emerge between scientist human capital and the propensity of a scientist to become an entrepreneur.

The definitions of the explanatory variables are summarized in Table 2.

Table 3 lists the means of each variable for the appropriate data sample

and Table 4 shows the simple correlation coefficient between the different variables.

Social Capital

Two different measures were used to reflect the extent of a scientist's social capital in the context of linkages with private industry. Such linkages are hypothesized to be conducive to generating both entrepreneurial opportunities and the access to expertise and experience in commercializing those opportunities through entrepreneurship. The first measure a binary variable taking on the value of one if the scientist has been a member of a scientific advisory board or the board of directors of a firm. A positive coefficient would indicate that social capital, as reflected by board membership, is conducive to the commercialization of university research. The second measure is *Industry Co-publications*, which reflects social capital and linkages between university scientists and their counterparts in industry and is measured as co-authorship between a university scientist and an industry scientist in the Science Citation Index using the Institute for Scientist Information (ISI) Web of Science citation database. The total count of papers coauthored with an industry scientist between the years of 1998 and 2004 was estimated using several search queries on the ISI database. Using the address fields within each publication value in the ISI database, Co-publications were identified as a private sector address if the terms *Co, Co Ltd, Inc,* or *LLC,* were found. Also, in order to not misidentify the University of **Co**lorado as a company, for example, the query forced the previously mentioned search terms to be standalone words, and not part of larger words. The coefficient is expected to be positive, which would reflect that university-industry scientist interactions are conducive to scientist entrepreneurship.

Characteristics of the Technology Transfer Office

Two dimensions of the technology transfer office at the university are included. The first is *TTO Employees*, which measures the mean number of employee. The measure is taken from the AUTM data base. A positive relationship would suggest that a greater commitment of TTO employee resources yields a higher propensity for scientists to become an entrepreneur. The second measure is *TTO Licensing*, which is obtained by dividing the number of employees dedicated to licensing technology by the number of administrative employees. This variable reflects the commitment of the TTO to licensing relative to other TTO functions. This measure is derived from the AUTM data base. A positive relationship would suggest that allocating a greater share of TTO employees to licensing would increase scientist entrepreneurship.

Financial Resources

There are two measures reflecting financial resources available to the scientist. The first is *NCI Grant,* which is the mean total NCI awarded to the scientist between 1998 and 2002. The award amount was obtained from the original NCI award excel sheet. If external funding of scientific research is conducive to scientific entrepreneurship, a positive coefficient of the *NCI Grant* would be expected. The second measure reflects the extent to which the NCI grant helped the scientist commercialize by obtaining patent protection of her invention. This measure was obtained from the survey of scientists.

Control Variables

Several other measures were included to control for the institutional context in which the scientist was working. The first is *NCI Center,* which is a binary variable taking on the value of one if the scientist is employed at one of the 39 nationally recognized cancer centers, and zero otherwise. A comprehensive cancer center integrates research activities across the three major areas of laboratory, clinical and population-based research. The comprehensive cancer centers generally have the mission to support research infrastructure, but some centers also provide clinical care and service, reflecting the priority that community outreach and information dismenation play at the centers. A positive coefficient would reflect that being located at a comprehensive cancer center facilitates scientist entrepreneurship. The second measure is *Ivy League*, which is a binary variable taking on the value of one for all scientists employed at Brown University, Cornell University, Columbia University, Dartmouth College, Harvard University, Princeton University, the University of Pennsylvania and Yale University. The third variable is *Public Universities*, which is a binary variable taking on the value of one for scientists employed at public universities and zero otherwise. Because they are at least partially financed by the public, state universities tend to have a stronger mandate for outreach and commercialization of research. This may suggest a positive coefficient.

The final control variable includes a dummy variable taking on the value of one if the patent was licensed. This may preclude entrepreneurial activity by the scientist, at least in the form of a startup, so that a negative relationship would be expected.

4. Results and Discussion

The results from the probit estimation are provided in Table 5. The results suggest that, in contrast to the consistent findings in the literature for entrepreneurship in general, in the case of university scientists, the personal characteristics of age and gender have no impact on the propensity for the scientist to become an entrepreneur. While both gender and age are consistently found to influence the decision to become an entrepreneur for the population at large, these are not found to have any statistically significance impact for the scientists included in this study.

Similarly, human capital, as reflected by the citations of the scientist, also have no statistically significant impact on the propensity for scientists to start a new firm. This is a contrast to the findings for the more general population. One interpretation of this disparity may be that this sample consists of scientists with exceptionally high levels of human capital. Variation in human capital for these scientists apparently have no additional impact on the decision to become an entrepreneur. By contrast, studies focusing on the broader population include observations with a much greater variance in levels of human capital, as well as a much lower mean level of human capital, so that human capital has consistently been found to influence entrepreneurial activity.

The measures of social capital are found to be the most important influences in the decision of a scientist to become an entrepreneur. Those scientists with higher levels of social capital, in that they are members of a scientific advisory board of a company, or they have co-authored articles with scientists working for a company, exhibit a systematically higher propensity to become an entrepreneur.

In addition, those scientists who suggested that the grant from the National Cancer Institute facilitated patenting their intellectual property also exhibited a higher propensity to start a new firm. This would suggest that the NCI is enhancing scientist entrepreneurship. The control variables have no statistically significant impact on scientist entrepreneurship.

Thus, the empirical results from analyzing why some scientists become entrepreneurs, while other colleagues do not, point to the importance of relationships and linkages forged through social capital, and in particular, to other scientists working in industry, as well as experiences gained by serving on a company scientific advisory board. Some of the more traditional explanations of entrepreneurship, and in particular, personal characteristics such as gender and age, do not seem to play an important role.

5. Conclusions

A number of indications suggest that the Bayh-Dole has not had much of an impact on generating entrepreneurial activity by scientists in the form of starting a new firm. Based on the respected and often cited data collected by the technology transfer offices at universities, and assembled by AUTM in a systematic and comprehensive manner, it would appear that even the most entrepreneurial universities generate only a handful of startups by scientists each year.

However, in this study, by asking scientists rather than the technology transfer offices of universities what entrepreneurial activities they actually engage in, a very different picture emerges. In fact, based on a data base of high profile scientists receiving large-scale funding from the National Cancer Institute, we find that university scientist entrepreneurship is robust and dynamic. The empirical results from this study suggest that around one in four scientists has engaged in entrepreneurial activity in the form of starting a new firm.

In addition, while most of the previous literature on scientist has been restricted to focusing on characteristics of the technology transfer offices and universities, due to the nature of the data being aggregated to the level of the university, in this study we are able to analyze the decision of a scientist to engage in entrepreneurial activity at the level of the individual scientist. The empirical results suggest that the decision to become an entrepreneur does not exactly mirror what has been found in the extensive literature for studies analyzing the broader population. Neither personal characteristics nor human capital seem to play an important role in the decision of a scientist to become an entrepreneur, as they do for the broader population. Rather, it is the levels of social capital, as measured by linkages to private industry, that increase the propensity of a scientist to become an entrepreneur.

An important qualification of the findings from this paper is that they are based on a special sample of highly successful top scientists in a narrow scientific field. Whether they hold across broader groups of scientists and for other scientific fields is an important issue that needs to be addressed in future research. However, the findings of this study would indicate that, scientist entrepreneurship is robust and prevalent in the Bayh-Dole era, and is certainly more prevalent than previous studies have suggested.

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Table 1 – Technology Transfer Office Mission Statements

Primary objectives of the UTTO	Percentage of times appeared in mission statement (%)
Licensing for royalties	78.72
IP protection/management	75.18
Facilitate disclosure process	71.63
Sponsored research and assisting inventors	56.74
Public good (disseminate information/technology	54.61
Industry relationships	42.55
Economic development (region, state)	26.95
Entrepreneurship and new venture creation	20.57
N = 128 TTOs.	

Source: Markman et al. 2005

Table 2 – Description of Independent Variables

Independent Variables	**Description**
Board	Binary variable, for scientists indicating that they sat on either a board of directors or science advisory board, Board=1
Industry Co-publications	The number of publications an NCI scientist shared with a private industry scientist
NCI Helpful	Binary variable, for scientists indicating that the NCI grant was helpful for patenting, NCI Helpful=1
Scientist Age	The age of the scientist
Male	Binary variable, where a male=1
NCI Grant	Total amount of funding received by the scientist
NCI Center	Binary variable, for a scientist whose institution is recognized by NCI as a comprehensive center for cancer research, NCI Center=1
Public Institution	Binary variable, for a scientist whose institution is a public institution, Public Institution=1
Ivy League	Binary variable, for a scientist whose institution is an Ivy League university, Ivy League=1
Average citation per publication	Aggregate number of ISI citations divided by the number of ISI publication a scientist received from 1998 to 2004
TTO Employees	The mean annual number of TTO employees dedicated to licensing and patenting
TTO Licensing Commitment	The number of TTO employees dedicated to licensing and patenting divided by administrative employees
Scientist Patent Licensed	Binary variable, for scientists indicating that the at least one of their patents were licensed, Scientist Patent Licensed=1

Table 3 – Means and Standard Deviations

	NCI Scientist	Patent Scientist	Interviewed Scientist
Variable	N=1693	N=392	N=140
Patent (%)	23.35 (0.42)	100.00	100.00
Startup (%)	-	-	25.71 (0.44)
Industry Co-publications	1.83 (3.57)	3.01 (4.89)	2.56 (3.73)
Board (%)	-	-	58.00 (0.50)
TTO Employees	8.66 (11.44)	9.14 (11.6)	8.95 (11.65)
TTO Licensing Commitment	1.68 (2.29)	1.31 (1.45)	1.22 (1.24)
NCI Grant (Dollars)	3,161,943 (3,196,918)	3,484,128 (3,795,993)	3,053,465 (2,674,288)
Gender (%)	77.87 (0.42)	87.85 (0.33)	88.57 (0.32)
NCI Helpful (%)	-	-	45.04 (0.50)
Scientist Age	-	-	56.76 (8.40)
Scientist Citations	1316.44 (2472.29)	1741.19 (2441.07)	1500.34 (1603.49)
NCI Center (%)	55.86 (0.50)	56.50 (0.50)	50.70 (0.50)
Public Institution (%)	53.91 (0.50)	48.10 (0.50)	49.29 (0.50)
Ivy League (%)	10.24	12.15	15.00

	(0.30)	(0.33)	(0.36)

Table 4 – Correlation Coefficients of Variables

	Startup	Industry Co-pubs	Board	TTO Employees	TTO Commit	NCI Grant	NCI Helpful
Startup	1						
Industry Co-pubs	0.166	1					
Board	0.346	0.031	1				
TTO Employees	-0.015	0.143	0.091	1			
TTO Commit	0.006	0.126	0.089	0.983	1		
NCI Grant	-0.053	0.073	0.12	0.15	0.134	1	
NCI Helpful	0.277	-0.01	0.213	0.205	0.2	0.106	1
Scientist Age	-0.137	-0.166	-0.066	-0.038	-0.041	0.041	0.004
Gender	0.157	-0.017	0.315	-0.015	-0.007	-0.058	0.086
Avg Citation per Pub	-0.066	0.066	0.104	0.07	0.078	0.193	0.09
NCI Center	-0.057	0.237	-0.093	0.232	0.268	-0.089	0.079
Public Institution	-0.075	-0.067	-0.031	0.278	0.292	0.073	0.132
Ivy League	-0.007	0.048	-0.1	-0.152	-0.138	0.015	0.122
	Scientist Age	Gender	Average Citation per Pub	NCI Center	Public Institution	Ivy League	
Scientist Age	1						
Gender	0.056	1					
Average Citation per Pub	-0.103	0.053	1				
NCI Center	-0.099	-0.145	0.022	1			
Public Institution	0.259	0.181	-0.193	-0.108	1		
Ivy League	-0.214	-0.007	0.127	0.175	-0.376	1	

Table 5 – Probit Regression Results Estimating Scientist Commercialization – Startups

Independent Variables:	*1*	*2*	*3*	*4*
Board	**1.277****** [3.747]	**1.502****** [4.456]	**1.525****** [4.517]	**1.488****** [4.628]
Industry Co-publications	6.425* [3.401]	**8.687**** [3.997]	**9.083**** [4.094]	**9.404**** [4.229]
NCI Helpful	**8.284****** [3.212]	**9.148**** [3.682]	**9.277**** [3.704]	**8.965**** [3.787]
Scientist Age		-2.102 [2.487]	-2.190 [2.496]	-2.123 [2.499]
Male		5.649 [1.006]	5.718 [1.008]	5.997 [1.018]
NCI Grant		-8.558 [9.982]	-8.601 [1.004]	-8.289 [9.929]
NCI Center		-2.277 [3.966]	-2.013 [3.886]	-1.875 [3.909]
Public Institution		-2.652 [3.995]	-2.675 [3.998]	-2.963 [4.008]
Ivy League		-6.405 [8.085]	-6.739 [8.131]	-7.586 [8.396]
Average Citation per Publication		-1.197 [1.011]	-1.168 [1.012]	-1.160 [1.013]
TTO Employees		-4.721 [9.528]		
TTO Licensing Employees			-1.286 [1.705]	-1.389 [1.748]
Scientist Patent licensed			1.580	-1.076 [4.046]
Constant	**-2.247****** [4.519]	-9.534 [1.715]	-9.366 [1.720]	-1.076 [1.768]
Observations	91	82	82	82
chi2	27.66	33.43	33.77	33.93
*** p<0.01, ** p<0.05, * p<0.1 Standard errors in brackets				
^ Note, all units have been multiplied by 10,000				