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University Commercialization Strategies in the Development of Regional Bioclusters*

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To analyze university contribution to economic development, the present study examines universities' technology transfer policies and their associated economic development impact. The article examines how a university defines itself as part of a region as well as what activities, if any, do university commercialization strategies in context of their regional environment affect spin-off activity. Furthermore, this study explores the ways universities contribute to regional economic development by examining existing theories and analyzing universities' relationships with both government and industry in two regions. This study draws from Roberts and Malone's (1996) selectivity–support typology and highlights this article's argument by comparing the commercialization strategies of world-class universities strategies in the development of regional biotechnology clusters in Massachusetts and in Connecticut. This article investigates the notion of whether universities can differently influence the economic development processes of the while still having successful commercial outcomes. These findings build on previous research (Clarysse et al., 2005; Degroof and Roberts, 2004; Powers and McDougall, 2005), which argues that low support–low selectivity policies may be more suitable to entrepreneurially developed environments, whereas high support–high selectivity policies are more efficient in entrepreneurially underdeveloped environments. Masachusetts Institute of Technology (MIT) is located in a strong technopole region, whereby many of its support structures for spin-off formation are provided by the regional infrastructure of the Cambridge–Boston region. In contrast, Yale University, which has an underdeveloped entrepreneurial context, has had to take a more proactive role in providing incubation capabilities to their spin-off projects. This finding supports a contingent based perspective of academic entrepreneurship, whereby low support–low selectivity policies are more fitted to entrepreneurially developed environments, whereas high support–high selectivity policies are more efficient in entrepreneurially underdeveloped environments.

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Introduction

In theories of regional economic development, universities play an important role. Several such theories view the university as an institution that generates knowledge, encourages the diffusion of new ideas on which innovation is based, and creates skilled personnel and entrepreneurs. Critically, in many theories the university is viewed as the basic

factor in a knowledge-based economy and a center around which new industrial clusters are likely to emerge. However, none of these theories see the university as a social agent. Furthermore, these studies do not provide a constructive generalized explanation to the ways universities can contribute to their local economy and whether there is only one way to achieve such a goal. The purpose of this study is to highlight the commercialization strategies taken by a university that influences its region's economy. To understand the role of the university in regional economic development, this study analyzes the duality of the relationships between university and industry. This article finds that universities have multiple ways they can make a positive impact on their local economy.

Traditionally, the roles of the university were to educate students and to conduct basic research. Over the years and throughout the scientific revolutions, universities have taken on another role, becoming central players in regional and national economic development. Different bodies of literature dealing with regional economic development and knowledge creation have touched on the role of the university. Industrial district theories still portray the universities as the source of knowledge for developing and updating technologies and an important source of qualified employees, analyzing them as institutions and not active agents (Markusen, 1996; Piore and Sabel, 1984; Porter, 1990). Collective learning and innovative milieu theories see the university as part of the knowledge creation process (Camagni, 1991; Keeble and Wilkinson, 1999; Lawson and Lorenz, 1999). However, the university is still seen primarily as a nonactive player in economic development.

One way to examine the role of the university in regional economic development is through the creation of start-ups from academic research. As a result, a new body of literature concentrating on the economic contributions of the university to society has developed. A prominent focus has been given to the contribution of the university to knowledge transfer. In this body of literature, the university provides knowledge with which industry can develop new technologies and promote economic development (Breznitz and Anderson, 2006; Clarysse et al., 2005; Di Gregorio and Shane, 2003; Henderson, 2006; O'Shea et al., 2005; Shane, 2004; Slater and Mohr, 2006). Most of the literature reviews this process as a new task for universities, a task that has been inevitably added to universities' roles due to historical changes (Etzkowitz et al., 2000; Minshall, Druilhe, and Probert, 2004). However, even these theories do not explain the exact ways universities promote regional economic development or why they vary in their ability to create start-ups at a regional level. An understanding of these different actions and their outcomes can provide a much needed explanation to how specific economic results can be achieved, allowing for feasible local economic predictions and appropriate expectations for universities.

To analyze university contribution to economic development, this study examines universities' technology transfer policies and their associated economic development impact. It examines how a university defines itself as part of a region, as well as what activities, if any, do university commercialization strategies in context of their regional environment affect spin-off activity. Accordingly, this study explores the ways universities in two regions collaborate with both government and industry. In particular, this article draws from Roberts and Malone's (1996) selectivity–support typology and highlights their

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argument by comparing the commercialization strategies of world-class universities strategies in the development of regional biotechnology clusters in Massachusetts and in Connecticut. It investigates the notion of whether universities can influence the economic development processes of the regions differently while still having successful commercial outcomes. Roberts and Malone put forward a typology of two entrepreneurial dimensions that are key in analyzing spin-off policies: level of selectivity and level of support of academic institutions. First, the low support–low selectivity policy consists of spinning off many ventures, but with little support. It reduces the cost of spinning off but seeks safety in numbers. Second, the high support–high selectivity strategy consists of spinning off a few well-supported ventures. It relies on picking potential winners and supporting them to increase their chance as much as possible (Degroof and Roberts, 2004).

Drawing from this typology, the present article argues that universities influence the economic development processes of the regions differently from one another. Different approaches to technology transfer at different universities can result in similar outcomes for respective regions. Thus, as this study shows, both top-down and bottom-up university initiatives can contribute to economic development. According to this study, each university, prior to launching its technology transfer policy, must evaluate the existing conditions in its institution and region and must implement the policy that will best suit its region's economy.

Why Is This Research Important?

With increasing pressure on universities to generate economic returns from federal research and development (R&D) funding, coupled with unemployment and outsourcing challenges, the debate as to how policymakers and academics can foster technology-based entrepreneurship from universities has become an important issue for national governments. Analysis of academic entrepreneurship through spin-offs in a comparative context has been particularly neglected yet is of growing importance for both researchers and practitioners (Chapple et al., 2005). By examining academic entrepreneurship in differing institutional environments this article seeks to provide an analysis on the use and limitations of existing conceptual approaches. A study of this sort can provide an opportunity for an in-depth longitudinal examination of each university's evolution and development in the context of commercialization strategies in a particular institution environment.

Second, for many institutions in the United States, the path to enhanced start-up creation is not an easy or smooth one. According to a recent study by O'Shea et al. (2005) the average research university in the United States generates a low average of 1.91 spin-offs per annum, despite attracting large funding endowments from both federal and industry sources. This mean value also masks a highly skewed distribution in the data in which the most productive university, Massachusetts Institute of Technology (MIT), spawned 31 spin-offs in one year alone (O'Shea et al., 2005). Successful spin-off efforts are difficult to mount, if only because of the continuing inability to make sense of the longitudinal character and the complex forces that give rise to spin-off creation. Furthermore, our knowledge of successful forms of action is no less limited. Despite having acquired information from a variety of spin-off programs, we have yet to distinguish attributes of successful programs that are institutional specific from those that are more generally essential. Moreover, we have not been able to tell institutional officials what procedures they should follow to initiate successful retention programs suited to their own financial needs and resources. This study addresses this limitation by assessing the mechanisms in which policies, operating both independently and through interaction, appear to influence an outcome in the form of biotech spin-off companies at the university level.

Finally, existing studies describe cases in which universities have contributed to the economy in general and to industry in particular. However, these studies do not provide a constructive generalized explanation regarding the ways universities can contribute to their local economy and whether there is only one way to achieve such a goal. The present article finds that universities can employ multiple strategies to make a positive impact on their local economy and outlines the mechanisms entrepreneurial universities can adopt to make positive regional economic impact.

Method

To accomplish this task, multiple sources of evidence were used to investigate MIT and Yale University's spin-off activity: semistructured interviews, MIT and Yale websites, books, and archival documents.

Furthermore, a number of quantitative databank sources were used for analysis: the National Science Foundation (NSF), Association of University Technology Managers (AUTM), National Research Council (NRC), US News & World Report, and the Center for University Performance Research.

MIT and Yale are very reputable research universities, with a strong life science research orientation. Theoretically, both should have a beneficial influence on the local economy, resulting in a leading biotech cluster. However, until the late 1990s, Yale, which had an aloof attitude toward the local economy, did not develop a biotechnology cluster, whereas in contrast MIT contributed to the development of one of the largest biotechnology clusters in the world (Saxenian, 1994). Biotechnology is a particularly appropriate subject for the nature of this article. The biotechnology industry relies on basic research mostly done in university laboratories. Furthermore, the biotechnology industry has been instrumental in the renewal of interest in university–industry relationships and the commercialization potential of university research (Blankenburg, 1998).

The present article is structured as follows: This section provides a brief overview of the contribution of the university to economic development through knowledge transfer, exploring the problems with the analysis of universities in existing bodies of literature. The following section provides a historical and political review at the regional and national levels in which the Boston–Cambridge and New Haven, Connecticut, biotechnology clusters developed to provide an understanding of the policy and economic framework in which the two universities operate. After that, the article examines the high selectivity–support policies employed by Yale to develop the biotechnology cluster in New Haven, contrasting this in the preceding section with MIT's approach, whereby a low selectivity–support model in the creation and the development of the biotechnology cluster was employed. The final section draws implications for each of these strategies and provides a view of the two cases, suggesting new ways to examine university contributions to local economies.

Regional and National Frameworks

This section reviews the environments in which Yale and MIT operate. This article finds that although Yale had to change its culture to foster technology transfer, MIT was created with a regional development focus in mind. Thus, Yale had to develop programs and promote technology transfer and entrepreneurship within the university at a time when MIT was leading the model of university–industry relationships.

Yale and Its Regional Environment

The New Haven metropolitan area is home to seven institutions of higher learning, which provide access to cutting-edge research in critical areas such as medicine, information technology, biotechnology, and architecture. The most notable of New Haven's schools is Yale University, the third oldest institution of higher learning in America. Yale was established in 1701 in Killingworth, Connecticut. It moved to its current location in New Haven in 1718.

Historically, Yale did not promote applicable research or industry collaboration. Hence, in 1994, Yale spent $224,939,000 on R&D and only registered 16 patents. It is interesting to compare these figures with MIT, which spent $374,768,000 on R&D in that year and registered 99 patents (NSF, 2003). Whereas Yale spent $14,058,388 per patent, MIT spent $3,785,535 per patent. These figures show that MIT produces more patents per research dollar. Furthermore, for many years Yale was not as active in technology transfer and by 1993 had spun out only three biotechnology companies. Until 1993, compared with MIT, which had spun out 30 biotechnology companies, Yale had spun out three companies, and only one, Alexion Pharmaceuticals, stayed in the region. These figures are broadly consistent with the reputation of Yale at that time as an institution that was only peripherally and episodically involved with the local economy and community. As President Richard C. Levin noted years later (Yale Office of Public Affairs, 2003):

> Outsiders have long regarded the presence of Yale as one of the city's major assets, but, except for episodic engagement, the University's contributions to the community did not derive from an active, conscious strategy of urban citizenship. It is true that our students, for more than a century, have played a highly constructive role as volunteers. Even a decade ago, two thousand students volunteered regularly in schools, community centers, churches, soup kitchens, and homeless shelters, but these volunteer efforts were neither coordinated nor well supported

> institutionally. When I became president in 1993, there was much to be done to transform Yale into an active, contributing institutional citizen . . .. In prior years, however, the university had taken a relatively passive attitude toward the commercialization of its science and technology.

With the exception of a few departments such as pharmacology, Yale faculty members were not encouraged to work on research with practical applications during this period. It was actually implied that the outcome of such involvement would have an unfavorable result on one's academic career. As one interviewee who served on the Yale faculty during the late 1960s observed, "One of the things that depressed me was that they did not want to do any application. You could consult but it was not a good status." There were important discoveries during that period, but the Office of Cooperative Research (OCR) had a somewhat passive view toward commercialization, and only a few discoveries were patented (One invention patented during this period was the profitable drug Zerit, which was licensed to Bristol-Myers Squibb and is part of the AIDS cocktail).

According to a Yale faculty interviewee:

> [There was] Very little applied research in biology, maybe in the medical school or pharmacology, chemistry department. In the biology department it was looked down upon. For example we made the first experiments on the transgenic mouse and they [OCR] considered that not to be worthwhile in terms of invention. Yale was very conservative for many years. Not a very active program. Yale actually lost a lot of intellectual property because of this culture. They did not patent on time.

An examination of the local industry prior to 1993 finds Connecticut as the host of five pharmaceutical companies: Pfizer, Bristol-Myers Squibb, Purdue, Bayer, and Boehringer Ingelheim. These companies have a major presence in the state, including research facilities; four of these companies are located in the New Haven metropolitan area. In 1995, a total of $1.2 billion was spent on pharmaceutical R&D in Connecticut itself (6% of the nation's total). The companies operated research-oriented facilities, staffed with scientists with a deep knowledge base in biomedicine. However, interactions with researchers at Yale and other local universities have been limited. At the time, none of these companies had established institutional relationships with local research institutes, relying instead on opportunistic specific interactions between their investigators and individual researchers at these institutes.

In summary, in the period prior to 1993 and up to 1996, the region had the availability of a knowledge base, skilled human resources, demand for goods and services, and a supporting industry—conditions that could result in the creation and development of a biotechnology cluster. Yet by 1993 there were only six local biotechnology companies (not including Exilexus and Genelogic, which had left previously) in Connecticut compared with 129 in Massachusetts at the same point in time. Unlike MIT, Yale is a late bloomer in fostering economic development. Only within the last decade has Yale begun to move away from the ivory tower approach and to recognize the importance of economic development near the campus. According to Leonard Bell, a former Yale professor who is founder and chief executive of Alexion Pharmaceuticals Inc., one of the oldest and largest New Haven-based biopharmaceutical companies, "Yale has gone from an insular focus on basic research to acknowledging in the early 1990s that there are exciting commercial opportunities in biotechnology and information technology."

Today the Connecticut cluster employs 17,985 people directly and 35,857 through indirect and induced employment. It consists of 49 biotechnology companies. Five of the biotech companies are publicly traded: Alexion Pharmaceuticals, Neurogen, Curagen, Gennesiance, and Vion Pharmaceuticals. Of the biotech companies, 24 companies, or 49%, of the biotechnology cluster in New Haven were created after 1996 with technology, ideas, or founders from Yale and with the help of the OCR. The majority of the biotechnology companies in this area work in the human therapeutic sector. This includes companies that work in more than one sector. The results in Figure 1 are based on the self-definition of 15 companies in the cluster (based on this study's survey).

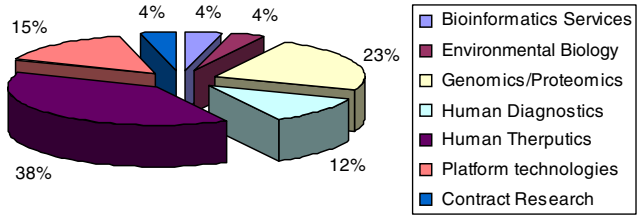

Figure 1. The Biotechnology Cluster in New Haven Metropolitan Area by Sector

R&D expenditures by the pharmaceutical industry in Connecticut have doubled since 1995 and today account for more than 12% of all R&D dollars spent by pharmaceutical companies nationwide (CURE, 2003)—compared with 6% of all R&D expenditures in 1995. The local pharmaceutical companies have significantly changed their behavior to give more weight to the local intellectual base. There are constant connections between local pharma and the local universities and research institutes, cultivated by Yale's OCR, the local biotechnology association, Connecticut United for Excellence (CURE), and the Office of Bioscience. Pfizer chose to use the local knowledge base by developing a direct relationship with Yale. Pfizer invested $35 million in a 60,000-square-foot clinical trial facility in downtown New Haven between Park and Howe Streets, an area owned by the State of Connecticut. Bayer initiated a scholar's program in 2003, under which a faculty member is appointed each year as a fellow and works closely with Bayer (Table 1).

The State of Connecticut has contributed to the success of Yale's technology transfer efforts by its support of the local biotechnology industry. Two entities represent the State of Connecticut in the effort to support economic development. The first is Connecticut Innovation (CI), created by the legislature in 1989. Connecticut Innovation was charged with investing in local companies to enhance economic development. The mission of the organization is "making equity investments in emerging Connecticut technology companies; providing essential, non-financial support to entrepreneurs; and conducting initiatives that address specific needs of Connecticut's technology sector" (State of Connecticut, 2005). CI was originally funded by the state, but since 1995 it has financed its equity investments solely through its own investment returns and not taxpayer dollars. CI has several ways of investing. Although generally it is an active investor, participating in creating a company, writing the business plan and helping to select the management team, CI sometimes joins in the bridge round, or series A, of the financing process. Carolyn R. Kahn, Ph.D., a bioscientist by training, has been appointed to lead CI's investments in bioscience (CI invests in many fields and not just biotechnology). Two major sources of funds are available to the local biotechnology industry:

(1) The Connecticut BioSeed Fund: This $5 million fund, administered by CI, provides seed capital to address the initial financial needs of young Connecticut companies, sustaining them until they are able to attract a lead institutional biotech investor for a Series A round of financing.
(2) The Bioscience Facilities Fund: This $60 million fund underwrites the development of incubator and lab space. The state legislature created the fund in 1998, with $30 million of state monies, and charged CI with its management. CI contributed an additional $10 million, using proceeds from its equity investments. Since then the fund has committed more than $20 million to finance more than 225,000 square feet of laboratory and related space (Connecticut Innovations, 2005).

The second entity is the Office of Bioscience. Under the second cluster bill in 2001, the State of Connecticut allocated $100,000 to establish the Office of Bioscience under the Department of Economic and Community Development. It was built to support start-up and existing companies in the region, to provide all the necessary information on conducting business in Connecticut, to bring new and existing out-of-state companies to the region, and to represent the life-science cluster of Connecticut in national and international events.

Other Connecticut incentives for the biotechnology industry include the following:

- 1996 Biotechnology Tax Incentive Package: This includes exemptions from sales, use and property taxes, and a 15-year carry-forward R&D tax credit.
- 1999 Tax Credit Exchange: Eligible companies that cannot use their research and development tax credits can exchange them with the state for 65% of their value.

Table 1. The Bioscience Cluster by R&D Expenses in Connecticut

R&D Expenses	Year End 2000	Year End 2001	Total Growth	Percent Growth
Biotechnology Companies	226,154,159	277,210,873	51,056,714	23
Pharmaceutical Companies	2,434,900,000	2,904,933,799	470,033,799	19
Academic Institutes	391,231,208	429,893,436	38,662,228	10
Total	$3,052,285,367	$3,612,038,108	$559,752,741	18

- Sales Tax Relief: Exemptions of 50% and 100% are available on certain biotechnology industry materials, such as tools, fuels, equipment, and safety apparel.

MIT and Its Regional Environment

The 1990s were a period of rapid growth in the Massachusetts biotechnology industry, and this growth has carried into the new century. By 2002, there were 275 biotechnology firms employing more than 26,000 people, and the dominant type of biotechnology activity in Massachusetts is related to medical science. MIT as a world-class educational institution has been very successful in fostering entrepreneurial approaches to technology transfer. According to the Technology Licensing Office (TLO) office records, more than 50 biotech IP spin-off companies have been spun out to the marketplace since 1980 (Table 2), with a further 50 start-ups estimated to be founded by academic inventors of the university. Given that more than 90% of MIT spin-offs are localized geographically and remained in the Massachusetts area, many of these MIT-related start-up companies play a central role in the formation and development of the Kendall Square and Greater Boston biocluster.

Yale and University-Based Technology Initiatives

Yale University is known for excellence in many fields, including the life sciences. However, its culture of noninvolvement in the community in general and industry in particular created a situation in which it failed to reap the credit for several important discoveries, such as the transgenic mouse. Following the arrival of a new president in 1993 and in response to concerns regarding to student and faculty recruitment, Yale made a conscious decision to invest in technology transfer and in its region's economy.

In a time when other universities were operating within clusters, Yale, even with a biomedical specialty, did not have a biotechnology cluster. Thus, the university wanted to cultivate a biotechnology industry to assist with the retention of star scientists and its attractiveness to bright students. An interview with a Yale administrator revealed the following:

> What was happening was the university was starting to become concerned that it would detract from our ability to compete, to attract the best and brightest students, the best and brightest faculty, et cetera, if we didn't do something about it . . .. First and foremost it was all about enhancing our reputation as a university, and two things come from that. One is our ability to attract and retain the best and the brightest faculty and students, and the second is to diversify the regional economy. Those were probably the principal reasons, and we weren't against making money, but we weren't making a lot at the time. It really wasn't the principal motivator; it really was about our reputation.

In addition, the city of New Haven was not a safe place for Yale's students. This was apparent with the shooting and death of a Yale undergraduate in 1990 (Sedgwick, 1994). Yale had to fight against crime to

Table 2. MIT IP Biotechnology Spin-Offs

Company	Year Founded	Company	Year Founded	Company	Year Founded	Company	Year Founded
Naxcor	1984	Proteinex	1989	IDUN	1994	Quantum Dot Corp	1998
Organogenesis	1985	Ariad Pharma	1990	Mosaic	1994	Sirenade Pharma	1998
Mattek	1986	Arris	1990	Algos Pharma	1995	Back Bay Scientific	2000
Applied Biotechnology	1987	Integra	1991	Morphogen	1995	Gel Med Science	2000
Biosurface	1987	One Cell System	1991	Nemapharm	1995	Elixir Pharma	2001
Enzytech	1987	Chemgenics Pharma	1992	Sontra Medical	1995	Spherics	2001
Immulogic	1987	Cubist	1992	Genetix	1996	3-DM	2002
Maritec	1987	Geltex	1992	Nemmorphics	1996	Iguazu	2002
Thermal Tech	1987	Stressgen Bio	1992	Sangamo	1996	Momenta	2002
AlphaBeta Tech	1988	Vazo Rx	1992	Avocet	1997	FoldRx	2003
Oculon	1988	HPJ	1993	Genitrix	1997	LightPharma	2003
Somatix	1988	Metabolix	1993	Petimmune	1997	Cardium Pharma	2004
Transgenic Science	1988	Pracis Pharma	1993	Agencourt	1998	Carisle Scientific	2004
Amira	1989	Reprogenesis	1993	Avicena	1998	Galenea	2004
Interneuron	1989	Acusphere	1994				

ensure the safety of its students by working with the city of New Haven to revitalize the downtown area and its neighborhoods. (To learn more about the four areas in which Yale decided to make a change, see the excerpt from Levin's speech given earlier in the article.)

The catalyst of the change in Yale's attitude toward applied research was the arrival of Levin as the 22nd president of Yale in 1993. In his first speech, Levin emphasized the importance of Yale's contribution to the local economy (Richard C. Levin Yale Office of the President, 1993):

> Our national capability in basic research was built by the far-sighted policy of public support for university-based science articulated during the Truman Administration and pursued consistently, though with varying intensity, ever since. Today, the scientific capability of American universities is the envy of the world. We neglect its support at our peril. As we seek to educate leaders and citizens for the world, as our discoveries spread enlightenment and material benefits far beyond our walls, we must remember that we have important responsibilities here at home. We contribute much to the cultural life of New Haven, to the health of its citizens and to the education of its children. But we must do more. Pragmatism alone compels this conclusion. If we are to continue to recruit students and faculty of the highest quality, New Haven must remain an attractive place in which to study, to live, and to work.

Levin found the university at a time of concern for recruitment of faculty and students and facing the need to create a secure environment for students. This allowed him to implement a vast social, cultural, and economic development change at Yale. Levin wanted Yale to become a contributing institution with a broad range of activities, which will include its role as an enhancer of economic development.

The Proactive Role of Yale's Technology Transfer Office

Yale's technology transfer office, the Office of Cooperative Research, was established in 1982. At the time, the office was mainly dealing with licensing and tracking patents. There was no real attempt to create or promote technology transfer from the academic to the industrial arenas, although a notable success during this period was the licensing to Bristol-Myers Squibb of the compound that became the highly successful drug Zerit. Initially this license produced little or no income to Yale, but by 1998 it was generating royalty income of $30 to $40 million annually. There were important discoveries during that period, but the OCR had a somewhat passive view toward commercialization, and few discoveries were patented.

In 1995, President Levin and Yale's provost at the time, Allison Richard, approached Gregory Gardiner, a former Pfizer executive, to take charge of the OCR with new roles and responsibilities. Gardiner, a former member of the Yale chemistry faculty, remembered the earlier lack of enthusiasm for research with practical applications and was eager to help bring about change. Gardiner joined the OCR as director in 1996 and restructured the OCR into an office with new responsibilities (OCR, 2003):

> The duties of the OCR include oversight for patenting and licensing activities, university inventions, and contractual relationships between faculty and industry. OCR staff work with Yale researchers to identify inventions that may ultimately become commercial products and services useful to the public. OCR staff engages in industrial partnerships to license Yale inventions. An important goal for the Yale OCR is to identify new ideas, cultivate venture funding for them, and facilitate their development into companies that become part of the New Haven economy.

There were many obstacles facing Gardiner and his team. One of the biggest challenges was to communicate the new priorities to the Yale faculty. In an interview, Gardiner said:

> I was asked many times by junior faculty, "If I get involved with new ventures through the OCR, will I still get tenure?" I told the committee [Educational Policy Committee of the Yale Corporation (the Yale trustees)] that we have to get Yale faculty to understand it is O.K. At MIT, history says that this is OK but at Yale we need a change of culture.

To achieve this goal the OCR had discussions with departmental chairs and faculty to explain the institutional change and Yale's commitment to economic development. They approached faculty who worked on applied research and had made important discoveries in the past. One of these faculty members recalls:

> The OCR people came to professors who had records in licensing or industry interaction and asked for ideas to patent and establish companies. They came

> to my lab; they knew I worked in Field Research A and Field Research B. One of the compounds went to [name of company]. They also recruited the management for the company. With the change, Yale has become more entrepreneurial but we are still responsible to our research and students.

An examination of the disclosure process found that there was a need to change the process and to make sure that the efforts were placed with the inventions that were most likely to succeed. This resulted in a major shift in OCR policies. There was an attempt to locate new inventions early, to examine them quickly, and to invest time and effort only in the strongest candidates. In addition, the upgrading of OCR practices led to the identification and recovery of more than $220,000 of unpaid royalties from several licenses (Office of Cooperative Research, 1998). Recognizing that 80% of patents from Yale were in the biomedical field, the OCR also opened another office in the School of Medicine with four staff members (Office of Cooperative Research, 1999).

The OCR is involved with the university's IPR policies, and today all intellectual property from the inventions of faculty or students belong to Yale. The OCR will patent the inventions. Yale does not have pipeline agreements on research outcomes. Companies can have an option or first right to license the technology from a sponsored research project, but nothing is prenegotiated. Faculty can sit on companies' scientific advisory boards, but they cannot take a full-time position. Faculty can only take a full-time position while they are on leave of absence from Yale. A Yale administrator said in an interview:

> They [faculty] can be assigned to advisory boards, they can be consultants, they can do all those things, but subject to our rules on conflict of interest, etc, the only way they can serve in a management or operative position is if they're not full time, so they'd have to be on a leave of absence, or something like that . . .. We believe that one of our principal reasons for existence is the teaching of undergraduates, and we expect all faculty members to participate in the teaching of undergraduates and that is a firm requirement.

Today, the OCR is involved in developing product scenarios, financial projections, and business strategies with the scientists. In many cases, the office is actively involved in building the company, looking for the right management and investors that will succeed in taking Yale's technology to the market. The OCR sees itself as a catalyst of economic development but hopes that in the future its involvement will not be as important. In August 1999, Gardiner retired, and Jonathan Soderstrom was appointed his successor as director of the OCR. As a result of the efforts by Yale in general and the OCR in particular, 39 biotechnology spin-offs were created, 24 have been established in the New Haven Metropolitan Area, and many more are in development (Figure 2).

Support Structures for Spin-Offs

During 1996–1997, the renewed OCR established direct contacts with venture capital firms. The goal was not only to persuade venture capital firms of the relevance of university technology but also to convince them to create ventures in New Haven. The hard work of seeking appropriate investors eventually paid off, and in 1998, after two years of effort, the first round of financing was concluded with $20 million for five companies. A Yale administrator said in an interview:

> We have all kinds of venture capital. One of the dirty little secrets is that although Boston thinks of itself as a major financial capital, we've got one that's even bigger. It's called Stanford Greenwich. When there was no state income tax, all the bankers used to live in Stanford Greenwich, not in New York City. So they all are still there, and that's where they have their finance companies.

The OCR is involved with firm creation on an unprecedented level, including the development of product scenarios, financial projections, and business strategies with the scientists. The OCR's activity is considered extreme on university–industry involvement scale. Even MIT, which is considered the top

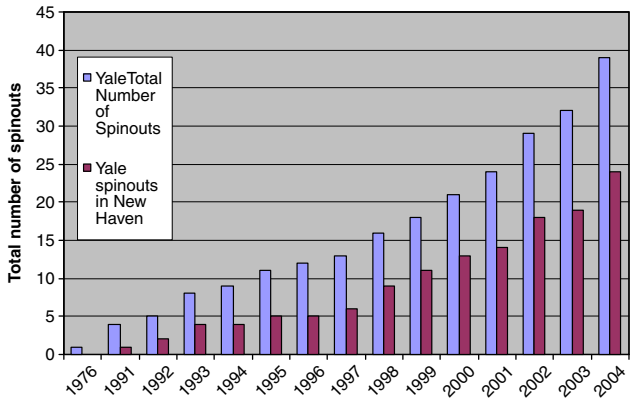

Figure 2. Yale Biotechnology Start-Ups by Location

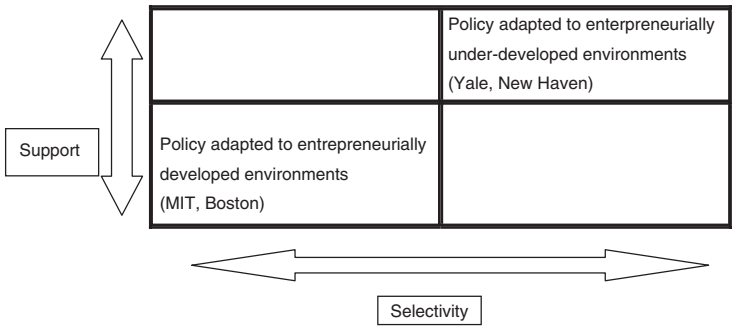

Figure 3. Roberts and Malone's (1996) Model of Support versus Selectivity

university in university–industry relationships, is not as involved in the creation of companies.

An equally important problem was the lack of laboratory space for new business ventures. To assist in the development, Levin used Yale's ability to recruit top talent and convinced Bruce Alexander to join Yale's Office of New Haven and State Affairs. Yale's ability to recruit top talent is demonstrated in the recruitment of both Gardiner and Alexander; this also confirms that Yale had a choice of who to recruit and when to recruit them. As explained by a Yale official:

> And it became clear that there's no better person to kick out the economic development kind of mission that Yale would like to have than a guy like Bruce, so Rick [Levin] convinced Bruce to take it on full time. It's one of those things where you sit around going, ''it's nice that everyone wants to do this,'' but how many people are going to be able to tap a guy like Bruce Alexander to be their economic development guru? The guy who redeveloped the Harbor place in Baltimore, the guy who did South Street Seaport in Manhattan. It makes us all look smart, but it's what a university like Yale can do.

The OCR, with the Office of New Haven and State Affairs at Yale led by Alexander, set out to build laboratory space close to Yale's scientists. Accordingly, the university attracted two developers, Winstanley Associates and Lyme Properties, LLC, both of which had experience in building labs. Winstanley bought the vacant headquarters of the telephone company on George Street, and Lyme took over the development and management of Science Park on north campus (where the university and the city had been trying to build a science park for years without success).

MIT and University-Based Technology Initiatives

Since its foundation as a public land grant institution, MIT has held a deep commitment toward fostering a culture of entrepreneurship on campus whereby it was envisaged students would not only think creatively but also would put their innovations into action. This stems from the concept of MIT's founder, William Barton Rogers, for a new kind of science-based technological university. He conceived a university with links to industry so that the research university's ''linear model'' could be combined with the land grant university's ''reverse linear model'' predicated upon deriving research goals from societal needs. Rogers stressed the pragmatic and practicable. According to the director of the MIT Entrepreneurship Center:

> MIT was founded in 1861 by an act of the Massachusetts State Legislature that charged the fledgling Institute with the ''development and practical application of science in connection with arts, agriculture, manufactures, and commerce.'' The Institute's motto, mens et manus—literally, ''mind and hand''—underscores MIT's philosophy of transforming visionary ideas into concrete realizations that benefit humanity

The MIT culture rewards the ''academic entrepreneur.'' As a result, there has been an open environment in which doing research with a company or a new venture is considered positive, provided it enhances the education of students and provides or contributes to opportunities to conduct important, nationally visible research. Thus, technology transfer at MIT is driven by its faculty and researchers.

Commitment of Academics toward Academic Entrepreneurship

What sets MIT apart from other intellectual centers is not that it contains extremely smart people with big ideas but rather that there are many smart people in one part of the world that is tailor-made to take their ideas and turn them into something real—and often profitable. According Charles Vest, a former president of MIT:

> Our faculty's commitment to deep, fundamental research and scholarship is matched by a desire to transfer new knowledge and technologies into the world in important and beneficial ways.

This central role of an entrepreneurial culture and tradition in harnessing academic entrepreneurship at MIT is also emphasized by Lita Nelsen, TLO director, in an interview in 2005:

> There is very much a word of mouth culture among the faculty almost to a point if you haven't done one [a spinout] yet you start to wonder what is wrong with you. Also if you are young and impressionable, as are students and you come and spend four years in this place you're going to meet at least twenty people who have started [a company] so you come out thinking everyone has done it and that I can do it to. So simply an exposure to entrepreneurship raises your expectation.

TLO Office and Entrepreneurial Development Programs

A number of organizational structures and practices facilitate commercialization of research at MIT. These include the TLO, the Sloan School Entrepreneurship Center, and the Deshpande Center for Technological Innovation entrepreneurship development programs.

Technology Licensing Office (TLO). MIT has one of the more active and successful technology transfer programs in the United States. The TLO office plays a proactive role in technology transfer activities. Rather than waiting for a technology pull, reacting to requests for licenses from interested companies, the TLO encourages faculty to promptly disclose inventions and then quickly and carefully evaluates the market value of inventions and obtains protection of intellectual property. However, according to Nelsen:

> Probably the difference between us and Yale . . . is how active they are in forming the company. We catalyze the company, introduce people together and if things come together we grant them a license . . .. But we don't actually get involved in business plan writing, or recruitment of management team, select the board . . .. Our process very much comes from the ground up.

Thus, the MIT TLO does not create or directly manage the creation of companies. Instead it acts as a "virtual incubator" and assists the inventors in the spin-out or licensing process. However, unlike Yale, which is trying to create a cluster of companies, MIT already operates in one and does not need to get involved in the actual creation and development of spin-offs. According to Nelsen in an interview in 2006:

> I attribute the difference [. . .MIT's commercialization strategies to Yale. . .] to the fact that there wasn't much infrastructure in the New Haven region, whereas in the Cambridge this infrastructure has built up overtime. So when people ask whether MIT have an incubator? Yes, it is the city of Cambridge, it is a geography experienced in high-tech entrepreneurship.
>
> The greater Boston area has a long tradition of starting up technologically ventures from their universities and also spinning out of corporations. It has trained lawyers, experienced accountants and real estate agents. We also have indigenous VC firms and management 'know how' who demonstrated capability to build and launch start-ups from university labs. This has also generated a feedback loop within the regions, whereby clusters feedback themselves and a cycle "success breeds success" culture has emerged.

Although TLO is closely attuned to the economic development mission of MIT and the entrepreneurial culture of the institution, it is important to mention the MIT does not engage in business plan support, does not take board seats at the company, or provide lab lab facilities to academic entrepreneurs to assist launching their business. In keeping with the university's supportive approach to faculty entrepreneurship, policies supportive of commercialization have evolved. A number of basic principles guide MIT's conflict of interest policies for technology transfer, and these basic principles also apply to start-up activities. MIT is acknowledged to have one of the strictest policies on managing these and other conflicts of interest arising from its licenses and collaborations with industry.

However, according to Nelsen:

> These clear policies, well thought out and consistently applied, are designed to facilitate start-ups. The simplicity, the strictness and no-exceptions rules for keeping MIT and its start-ups separate actually help keep things moving, because negotiations do not get bogged down while committees ponder over exceptions and risks.

Entrepreneurship development programs. MIT has supplemented a rigorous engineering curriculum with formal and experiential education in entrepreneurship, drawing on the local alumni base and faculty role models. This program, and perhaps more importantly the underlying culture of the institution, has a strong influence on students and graduates. Supporting entrepreneurial activity has long been a very important part of the culture of MIT, but its role and importance have accelerated dramatically. This aspect of MIT's culture is fostered in a number of ways.

The MIT Deshpande Center for Technological Innovation awards $50,000 Ignition Grants and $250,000 Innovation Grants to MIT faculty first to catalyze demonstration of new business ideas based on their research and then to help move those new ideas to market by funding later stage research and matching each project with a Catalyst mentor from the industrial or investment community. It also offers a Venture Mentoring Service whereby MIT alumni offer to mentor MIT entrepreneurs. In certain cases, retired venture capitalists, entrepreneurs, and chief executive officer mentors are given offices on campus to be in close proximity to the MIT community.

The Center for Entrepreneurship, located at the Sloan School of Management, aims to engage students and faculty throughout the institute and to provide research and educational programs in electronic commerce and in new product and venture formation. According to the director of the MIT Entrepreneurship Center, MIT is not satisfied with the production of knowledge, patents, and degrees but wants these to be applied to commercial use. Thus, the university tries to train its own staff and students to become competent enough to make high-tech ventures successful:

According to the director of the MIT Entrepreneurship Center:

> MIT scientists, engineers, and managers believe that it is not enough merely to invent a new product, concept or technology. The measure of success is global commercialization and widespread acceptance of their innovations.

Discussion and Conclusion

This study compared two approaches to technology transfer from universities to industry: top-down and bottom-up initiatives. The study compared these approaches at Yale and MIT, two world-class leading research universities. The results show that different approaches to technology transfer and commercialization at universities can result in similar positive impacts on the local economy.

Although Yale is one of the strongest universities in life sciences in the United States, with plenty of resources, prior to 1993 it had spun out only three biotechnology companies and had very few patents and licenses. Its passive attitude toward applied research and technology transfer created an obstacle for the creation of clusters. Thus, in 1993, following the arrival of Levin as Yale's 22nd president, Yale decided to invest in four areas, one of which was economic development through technology transfer. Yale chose to approach the change through top-down initiatives to create a new entrepreneurial environment at the university. Thus, Yale chose to rebuild its technology transfer office (TTO) to push for spin-off creation and its location in the region. Furthermore, the university contributed to the creation of new science parks in the region and the revitalization of the downtown area and the surrounding neighborhoods. Yale's economic development impact on the local region can be seen in the growth of the number of biotechnology companies in the region from 6 to 49 with a total number of 35,857 employees in the industry. The local pharmaceutical industry has changed its relationships with the local academic base. Today local pharmaceutical companies have research programs with Yale and local biotechnology companies. The total R&D of the pharmaceutical industry in Connecticut represents 12% of the total R&D that the industry does nationwide. Yale University spun out 39 biotechnology companies, which engage in research projects with the university and provide internships for its students.

On the other hand, MIT has a long and distinguished track record of involvement and commitment to promoting economic development. Undoubtedly, the university's land grant heritage, with its emphasis on the importance of service and application of

research, played an important role in these activities. MIT also nurtured a long-standing mission of service to its state and national interests while at the same time creating a bottom-up entrepreneurial culture and some novel approaches to technology transfer. MIT is populated with a large number of star scientists, in science, engineering, and biomedical disciplines, who are committed to generating, disseminating, and preserving knowledge and to working with others to bring this knowledge to bear on the world's great challenges. Thus, to support these resources, MIT's story is largely about a bottom-up approach using a low support–low selectivity model toward technology transfer policy. The MIT story is also about a formal, deliberate approach to commercialization, which is supported by a university mission that is advocated by university leaders that view MIT's cooperation with industry favorably. However, it is also a story of history, leadership by key individuals, and the development of a robust entrepreneurial culture within the university and its surrounding environment.

Major Research Results

From this study, it can be seen that the success of science and technology policy is related to the institutional arrangements that enable knowledge transfer and innovation in a process-oriented mode. Whereas Yale chose high support–high selectivity initiatives and micromanagement of technology transfer, MIT chose to stay with in its entrepreneurial culture and implement up until recently a low support–low selectivity models in terms of the creation and development of start-ups. Both contributed to the creation of a vibrant biotechnology cluster. Second, the choice of commercialization initiatives at universities needs to be made after careful evaluation of the region in which the university operates and the current conditions for economic development. Yale chose its top-down technology transfer policy to rebuild a new entrepreneurial spirit at the university. MIT, which was founded with industry collaboration in mind, chose to build on the existing institutional and regional environment in technology transfer and to implement its policy through largely bottom-up initiatives. Third, for technology transfer policy to succeed, it is not enough for a university to initiate top-down changes—a real cultural change within the university has to occur. It was not enough for Yale to change its technology transfer office. Central administration had to convince faculty that the university supports their applied research and industry related activity and to allow faculty to change their attitude to become entrepreneurs.

In summary, there are many ways universities can have a positive contribution to economic development. However, the ways universities choose to make their contribution must compliment the existing conditions for technology transfer and commercialization at both the university and the region in which it operates.

Theoretical and Managerial Implications

Technology transfer and the commercialization of university research is a fundamental part of U.S. emerging industrial development strategy and in terms of building high value-added jobs. However, for many countries investments in funding of university research projects and institutes have occurred in a vacuum in that there is an incomplete understanding of how such investments will lead to the anticipated industrial development benefits. By building on Roberts and Malone's (1996) model of support versus selectivity, the present article shows that many models for university–industry and technology transfer can result in similar positive economic impacts. The present study therefore argues that the development of strategies to aid spin-off companies should be tailored to the specific needs of the spin-off and the institution from which they emerge. The typology provides dimensions along which policymakers and practitioners can shape their thinking about biotechnology start-ups. This article's strength is in the choices it offers university heads and policymakers, revealing that different approaches to technology transfer and commercialization can lead to similar positive impacts in local economic development. As a consequence, this article provides the first step toward the construction of a different theoretical conceptualization of the university as an actor in regional development.

Limitations and Future Research Directions

This research is limited to the results from the two case studies of two leading research universities in the United States. Although case studies provide rich insights into a specific situation, it is difficult to generalize about the studies as a whole. Thus, further

analysis needs to be conducted using other universities and both the bottom-up and top-down initiatives to examine their impact on the creation of local bioclusters. This article focuses on bioclusters; thus, the impact of the studied universities on other technological clusters has not been, but should be, examined.

References

Blankenburg, Stephanie (1998). University-Industry Relations, Innovation and Power: A Theoretical Framework for the Study of Technology Transfer from the Science Base. Working Paper 102. ESRC Center for Business Research, University of Cambridge.

Breznitz, Shiri M. and Anderson, William. (2006). Boston Metropolitan Area Biotechnology Cluster. *Canadian Journal of Regional Science* 28(2):249–264.

Camagni, Roberto (1991). Local "Milieu" Uncertainty and Innovation Networks: Towards a New Dynamic Theory of Economic Space. In: *Innovation Networks: Spatial Perspectives*, ed. R. Camagni. London: Belhaven, 121–142.

Chapple, W., Lockett, A., Siegel, D., and Wright, M. (2005). Assessing the Relative Performance of UK University Technology Transfer Offices: Parametric and Nonparametric Evidence. *Research Policy* 34(3):369–384.

Clarysse, B., Wright, M., Lockett, A., Van De Velde, E., and Vohora, A. (2005). Spinning Out New Ventures: A Typology of Incubation Strategies from European Research Institutions. *Journal of Business Venturing* 20:183–216.

Connecticut Innovations (2005). Funding Opportunities. Available at: http://www.ctinnovations.com.

Connecticut United for Research Excellence (CURE) (2003). *Economic Survey Report*. New Haven. CT: Yale University.

Degroof, Jan Jack and Roberts, B. Edward (2004). Overcoming Weak Entrepreneurial Infrastructure for Academic Spin-Off Ventures. *Journal of Technology Transfer* 28(2):249–264.

Di Gregorio, Dante and Shane, Scott (2003). Why Do Some Universities Generate More Start-Ups than Others? *Research Policy* 32:209–227.

Etzkowitz, Henry, Webster, A., Gebhardt, C., and Terra, B. (2000). The Future of the University and the University of the Future: Evolution of Ivory Tower to Entrepreneurial Paradigm. *Research Policy* 29(2):313–330.

Henderson, Rebecca (2006). The Innovator's Dilemma as a Problem of Organizational Competence. *Journal of Product Innovation Management* 23(1):5–11.

Keeble, David and Wilkinson, Frank (1999). Collective Learning and Knowledge Development in the Evolution of Regional Clusters of High Technology SMES in Europe. *Regional Studies* 33(4):295–303.

Lawson, Clive and Lorenz, Edward (1999). Collective Learning, Tacit Knowledge and Regional Innovative Capacity. *Regional Studies* 33(4):305–317.

Markusen, Ann (1996). Sticky Places in Slippery Space: A Typology of Industrial Districts. *Economic Geography* 72(3):293–313.

Minshall, T., Druilhe, C., and Probert, D. (2004). The Evolution of "Third Mission" Activities at the University of Cambridge: Balancing Strategic and Operational Considerations. Paper presented at the 12th High Tech Small Firms Conference, University of Twente, The Netherlands, May 24–25.

National Science Foundation (NSF) (2003). Table B-32, Total R&D Expenditures at Universities and Colleges, Ranked by Fiscal Year 2001. Available at: http://www.nsf.gov/statistics/nsf06329/pdf/tabb32.pdf.

Office of Cooperative Research (1998). 1996–1998 Yale OCR Annual Report "From Bench to Bedside." New Haven, CT: Yale University.

Office of Cooperative Research (1999). 1998–1999 Yale OCR Annual Report "Partnerships for a Brighter Future." New Haven, CT: Yale University.

O'Shea, R.P., Allen, T., Chevalier, A., and Roche, F. (2005). Entrepreneurial Orientation, Technology Transfer and Spinoff Performance of U.S. Universities. *Research Policy* 34(7):994–1009.

Piore, Michael J. and Sabel, Charles F. (1984). *The Second Industrial Divide: Possibilities for Prosperity*. New York: Basic Books.

Porter, Michael E. (1990). *The Competitive Advantage of Nations*. New York: Free Press.

Powers, Joshua B. and McDougall, Patricia (2005). Policy Orientation Effects on Performance with Licensing to Start-Ups and Small Companies. *Research Policy* 34(7):1028–1042.

Richard C. Levin Yale Office of the President (1993, October 2). Beyond the Ivy Walls: Our University in the Wider World. Available at: http://www.yale.edu/opa/president/speeches/levin_inaugural.html.

Roberts, Edward B. and Malone, Denis E. (1996). Policies and Structures for Spinning Off New Companies from Research and Development Organizations. *R&D Management* 26:17–48.

Saxenian, AnnaLee (1994). *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.

Sedgwick, John (1994, April). The Death of Yale. *GQ* 64(4):182.

Shane, Scott (2004). *Academic Entrepreneurship: University Spinoffs and Wealth Creation*. Cheltenham, UK: Edward Elgar.

Slater, Stanley F. and Mohr, Jakki J. (2006). Successful Development and Commercialization of Technological Innovation: Insights Based on Strategy Type. *Journal of Product Innovation Management* 23(1):26–33.

State of Connecticut (2005). Connecticut Counties. Available at: http://www.ct.gov.

Yale Office of Public Affairs (2003). President's Welcome. Available at: http://www.yale.edu/opa/president/index.html.