CHAPTER ONE

Introduction

Universities, viewed as fountains of knowledge, produce the world's most important resources: young minds and an educated labor force, which in turn produce cutting-edge research and innovative ideas and products that contribute directly to economic development. Thus, universities contribute directly to a region's economic growth, making universities a highly desirable and almost essential resource for a region.

The economic development effected by a university is evaluated by the amount of technology commercialization it generates. Patents, licenses, and spin-out firms are easy to quantify and use as a measurement of university productivity. Technology firms tend to develop near universities as a result of the knowledge spillover generated by university research. The mere existence of a university in a region, however, is not a guarantee of economic success.

So what determines how well a region benefits from the presence of an innovative research university? There are two main factors: the ability of the university to transfer knowledge to the public domain and to commercialize technology, and the region's ability to absorb that information. Some regions are better able than others to innovate and commercialize technology. By focusing on university knowledge transfer and technology commercialization, the fountain of knowledge, we can evaluate whether the research that universities are expected to do is beneficial and valuable to local economic development—after all, it is demanding and requires many resources of these higher education institutions.

The Fountain of Knowledge analyzes two world-renowned universities, their investment in technology commercialization, and the outcome of that contribution in their local economies. This book has three main arguments. One is that the way in which a university goes about improving its technology-transfer capability matters. Conducting a focused and thoughtful comprehensive change that includes all sections of the university will improve commercialization. Second, by choosing a particular path of change, the university also changes its role and its ability to contribute to the region. Third, not all changes will positively affect the local economy.

THE ROLES OF THE UNIVERSITY

The evaluation of university technology commercialization is vital, considering that the traditional roles of universities have been research and teaching. These original roles of universities have been intensely discussed over the past century at both national and regional levels. Should universities remain islands of research, free of politics, economics, and social class? Or should they participate as active players in local economies and societies?

Historically, universities were the domain of the upper classes, who studied such esoteric subjects as literature and philosophy. Over time, universities began to serve the general public, offering more practical subjects, such as applied research, and training students for professions like medicine and law. By the early 1900s universities had become recognized as regional and national engines of growth.

The modern university, as it developed in the nineteenth century, is an important source of new knowledge and technologies, with the potential to be commercialized (Scott 1977). Today's model of the university has a public-service component, offering a wider base for research and teaching—both of which have the power to promote social change. According to Scott (1977), the service component was a direct result of changes in modern society—that is, growth in the number of students and demand for skilled workers. The university service component was influenced by a neoliberal economic perspective. From that perspective, universities are evaluated on the basis of their contribution to the economy. Therefore, in most countries, universities that rely heavily on public funding are pressured to "pay back" the community and act like responsible citizens (Russell 1993).

The pressure on modern universities to pay back the community has created what is known as the "third role" of universities. Many universities are now obliged to make a contribution to society through research and development (R&D), collaborations, and technology transfer with industry (Minshall, Druilhe, and Probert 2004). Collaborating with industry is a significant change from the original mission of the university, representing an expectation of service that many institutions are not ready or willing to make. However, there is an apparent public benefit for industry collaborations. Universities are an important source of a skilled labor force that is often trained through public funding. Moreover, commercialization can be a solution for universities' financial constraints as well as a way for students to gain industry experience. Hence, university-industry collaboration and proximity promote the formation of industry and economic growth.

However, there is still a debate over university-industry relationships. Studies of higher education institutions emphasize the ability of universities to become important contributors because they are centers of "free" thinking. The idea behind the tenure-track position was to allow faculty to work on new ideas without any constraints. Some of the most interesting innovations, such as electricity, started with a totally different research question in mind. In many cases the discoveries were even found in different schools of thought. Should we predicate what universities need to work on because we know they are capable of producing the next generation of technology? Are we not limiting the fountain of knowledge this way to a mere drizzle?

Some scholars believe that there should be a separation of university and industry. Those scholars claim that academics do not possess the business knowledge to determine which projects should be commercialized, nor should public universities provide services to a specific private market or a particular industry. Technology transfer requires universities to be attuned to, and work with, industry's business perspective. Spin-out companies in particular require different business skills from those that universities are normally equipped with, such as expertise in entrepreneurship, business development, and venture capital. Furthermore, technology-transfer offices need to be able to assess inventions and decide whether they have a commercial value. Thus, they need to employ specialists or hire consultants to evaluate the technology, which is often expensive. Is this the knowledge we are looking for when we consider universities as fountains of knowledge?

TO MEASURE?

Many claim that by being fountains of knowledge, universities already contribute to regional and national economies. Hence, their contribution cannot be ignored and should be used to improve the quality of life and the economic situation of the region and community in which the university is located. There are two ways to measure the impact of a university on a regional economy. The classic, or "short run," method is to determine the institution's contribution to the annual flow of regional economic activity. The "long-run" method focuses on the contribution of the institution to the continuous growth of human capital in the region (Beck et al. 1995).

The short-run impact—actual dollars flowing into a region due to the mere presence of the university—can be measured by the purchases made by the university in the region: office supplies, rent, food, and services; salaries for employees, some of whom live in the region and spend their wages in the region. Outside funds like donations, grants, and state and federal government funding to the university are also considered in determining a university's economic impact. In this way a university is measured only by direct input and output. University contributions that are not measured in dollar amounts, such as graduate students' firms and firms' products based on university research, are not taken into consideration.

The long-run impact measures "the future income stream of graduates who stay to work in the area" (Beck et al. 1995, p. 246) and the economic impact of graduate students' firms and firms with products based on university research and patents. Measuring long-run impact provides a method to calculate the return on tax invested in higher education. Studies have proved that higher education leads to higher levels of income. In urban areas, the presence of universities seems to affect the growth rates, earnings, and composition of employment. Hence, the ability of a university to patent, license, and spin out firms has a direct impact on the long-run economic development of a region, which is the focus of this book.

THIS BOOK

This book examines the cases of two prominent universities, Yale University and the University of Cambridge, that have made policy, culture, and organizational changes to improve their abilities to commercialize technologies and to have a wider impact on their respective local economies. Interestingly, these two universities took different approaches to technology transfer and had different outcomes, both for themselves and for their local regions. Though previous studies have found university investment in technology commercialization to have a positive impact, I found that not all results have been positive.

I also consider other factors that may have been responsible for the changes at both locations. For example, a university's ability to disseminate academic ideas to the private market and to contribute to regional economic growth frequently depends on internal mechanisms and resources rather than on formulaic technology-transfer models.

Moreover, universities do not exist in a vacuum—they are influenced by social and economic processes and politics. Each university should be analyzed in its historical and environmental arena. This kind of analysis is a more valid indicator as to the ability of a university to disseminate academic ideas to the private market and to commercialize inventions.

I have analyzed the two universities in lieu of the local biotechnology industry. This industry relies heavily on university research. As a result, ties between biotechnology companies and specific research institutes are easy to identify. Biotechnology is a "new" industry, with its earliest companies established in the 1970s,[1] but biotechnology itself is not a new phenomenon. What we know as modern was the result of several breakthroughs in molecular biology during the mid-twentieth century (Acharya 1999). In 1953, James Watson and Francis Crick, from the University of Cambridge, identified the structure of DNA. This breakthrough was followed by the development of monoclonal antibodies, on which diagnostic kits in the therapeutic industry are based. First developed at University of California–San Francisco and Stanford University in 1973, the process of cutting and rejoining DNA to produce recombinant DNA that could replicate a host cell—known as cloning—revolutionized modern biotechnology.

Research at universities has led to the identification of many new antibodies, proteins, and potential drugs. In many respects, the biotechnology industry has been launched from universities and research institutes, thus creating a clear and direct connection between biotech industries and universities, and providing an excellent case study for this book. While university inventions are usually licensed to private companies, the companies stay in constant contact with the university researchers, especially in their early stages of research, to assist in product development (Kenney 1986).[2] Therefore, the biotechnology industry has been instrumental in the renewal of interest in university-industry relationships and in the commercialization potential of university research (Blankenburg 1998).

Both Yale and Cambridge have been cited as strong research universities in life sciences, instrumental to the development of regional biotechnology clusters. Yale is situated in New Haven County, which has the largest biotechnology industry agglomeration in Connecticut. The biotechnology industry in New Haven, which in 1993 consisted of only of six companies, had grown to forty-nine by 2004 and seventy firms by 2013, making New Haven seventh in the United States by number of biotech companies per capita and third in the nation by per capita research grants (Ernst & Young 2001; US Department of Health and Human Services and National Institutes of Health and US Census 2008). The majority of the biotechnology companies in this cluster have spun out of Yale University. Similarly, the University of Cambridge is located within Cambridgeshire County, with approximately 154 biotechnology companies in this county, representing about a third of all UK biotechnology industry (Sainsbury 1999; Greater Cambridge Greater Peterborough Enterprise Partnership 2013).

Despite its strength in the life sciences, Yale University did not promote technology transfer and commercialization until the mid-1990s. Moreover, its disapproving attitude toward applied research caused the university to lose many faculty members and patents to other universities. However, in 1993, with a change of leadership and concerns for the university's eminence, Yale started to invest in technology transfer and local economic growth, and the investment paid off handsomely. Similarly, in the late 1990s, as a result of government pressure, the University of Cambridge made changes and investments in its technology-transfer policy. But, as we shall see, the university-industry relationships that were formed near Cambridge did not result in revenues for the university, nor did they lead to regional economic growth.

Why such different outcomes? Both institutions are distinguished universities conducting world-class research in the biosciences, and both decided by the late 1990s to make changes to their technology transfer mechanisms. The ways they implemented those changes were very different, however, and as a result, the changes produced significantly different outcomes. As the goal here is to investigate universities' technology-transfer capability, rather than compare the two university cases by output, this book looks at their unique policies, organizational structure, and commercialization culture, all of which have influenced their technology-transfer capabilities.

THE LITERATURE DEBATE

Although many studies treat technology transfer as a single process rather than focusing specifically on policy and organization, the studies can be divided into two categories. First, some scholars view the university technology-transfer process, including organization, as a factor in the university's ability to commercialize innovative ideas (Feldman and Desrochers 2003; Siegel, Waldman, and Link 2003a; Rothaermel, Agung, and Jiang 2007). Other scholars focus specifically on university technology-transfer output in the form of patents, licenses, and spin-outs (Di Gregorio and Shane 2003; Mowery and Sampat 2001a; Shane 2004).

In terms of the impact of technology transfer on the university itself, the role of the university as a public, nonprofit educational institution is becoming blurred. Universities are now considered leading players in today's global economy, players that can promote and establish certain regions as leaders of the world's economy. Thus, universities are being examined and pressured to prove their ability to innovate as well as to transfer their innovation to the public domain. By allowing universities to own and commercialize their innovations, their success is now measured by a new factor—technology commercialization.

This book continues the investigative tradition of the scholars who believe that to understand the ability of a university to transfer academic ideas to the private market, we must understand technology commercialization investment and processes as a whole. However, unlike other studies that analyzed one or two universities and reviewed one or two factors that affect technology commercialization (e.g., policy, employee characteristics), this book reviews factors identified by previous studies in a comparative study that adds the environment and history of a university location to its analysis. Technology commercialization functions differently in different universities, and as such it has been proved to make a difference in a university's ability to patent, license, and spin out (Feldman et al. 2002; Kenney and Goe 2004; Shane 2004; Siegel, Waldman, and Link 2003a, 2003b). In most studies, universities' investments in technology transfer and commercialization are viewed positively. Interestingly, studies show that although many universities invest heavily in technology transfer, not all show an increase in output as a contribution to their local economy.

A TALE OF TWO UNIVERSITIES

Enter the arena two of the world's most renowned universities: the University of Cambridge in the United Kingdom and Yale University in the United States. During the 1990s both universities found themselves under pressure to make an impact and contribution to their local economies.

Both institutions made a vast change in their policies and processes to be able to do so.

More specifically, the University of Cambridge, which had strong university-industry relationships and a large number of university spin-outs, executed changes to its policy and organization without consideration as to how those changes would affect other regional players. Hence, the implementation of these changes damaged its technology-transfer capability, as was evident in the reduction of its spin-outs and the response of the local industry. In contrast, Yale University implemented different policy and organization changes while collaborating with other regional players and local industry. The result was a positive impact, evident in the growth of university spin-out and local industry response.

Importantly, the difference between the changes undergone by these two universities lies in the process of change. Yale made comprehensive changes to the entire university's approach to technology transfer that included policy, culture, and organization; the University of Cambridge made partial changes to some of its intellectual property rights policy and organization. Moreover, the velocity of change was different. Yale made a decision to change and started one process that took three years. Cambridge, conversely, made incremental changes to its policy and organization over a period of eight years. Last, while Yale made a conscious decision to include the local industry and region in its changes, Cambridge made changes within the university without input from or cooperation with the local industry or region. Those changes worked out in different ways for the regions, for the firms and financiers in them, and for the universities.

The University of Cambridge

> The mission of the University of Cambridge is to contribute to society through the pursuit of education, learning, and research at the highest international levels of excellence. (University of Cambridge 2005b)

As one of the leading universities in the world, the University of Cambridge is strong in the sciences, specifically in engineering and biomedicine (*Times Higher Education* 2013). It was established in 1209 by scholars who had left Oxford University. The first college, Peterhouse, was established in 1284, creating the foundation for the collegiate system—a defining feature of the university.

Today, Cambridge is a complex web of independent departments, colleges, and research institutes, where central university administration is weak compared to that of other universities in Europe and the United States.[3] Students and most faculty members belong to both a department and a college. The colleges are autonomous institutes that select their own faculty and students, although they are connected to the university through membership in the university council and representation on different boards. Thus, college faculty do not necessarily have positions in a university department, and university department faculty do not necessarily have to hold a position at a college. Students, however, always belong to both the university and a college. The colleges differ by financial capability, educational strengths, and students. Three accept only women; most accept both undergraduates and graduate students. The financial capability of the colleges, including the ownership of land, has contributed to the development of the high-tech industry in the region through the creation of Cambridge Science Park by Trinity College and the St. John Innovation Centre by St. John's College (Gray and Damery 2004).

Cambridge is also known for its relaxed, noncontrolling "policy toward commercial exploitation of academic know-how and links with industry generally" (Segal Quince Wicksteed 1985, 47). The authors of the *Cambridge Phenomenon* are referring here to the free hand that academics are given in Cambridge regarding the commercialization of their research. In applied sciences, it is presumed that faculty will be involved in consulting and research with industry. Thus, it is not surprising to find a growing biotechnology cluster in the region. However, a close examination of the 153 biotechnology companies in Cambridgeshire County found that only 16 percent of the companies are spin-outs from the University of Cambridge (compared to 40 percent of the companies in New Haven).

Figure 1.1 illustrates the constant growth in the number of patents applied for by the University of Cambridge. These figures reinforce data on the academic strength of Cambridge, ranking the university as one of the top patent owners, along with Massachusetts Institute of Technology (MIT), California Institute of Technology, Stanford University, and Johns Hopkins University (US Patent and Trademark Office 2003).[4]

Unlike many other top patent-owning universities, Cambridge is a public university, heavily dependent on government funding. From 1999 to 2012, the University of Cambridge's income grew by 186 percent (from £293 million to £860 million), including an increase of 192 percent in income from grants and contracts (*Times Higher Education* 1999). An indicator of the university's pledge to academic excellence in the biomedical field is the fact that half of funding is dedicated to clinical medicine and

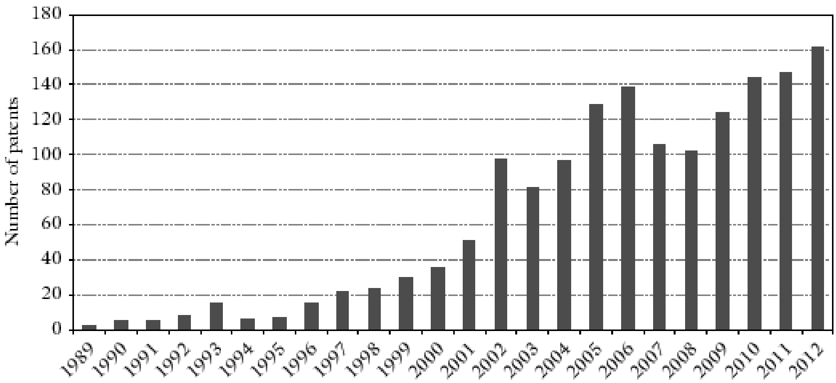

FIGURE 1.1 University of Cambridge by patents, 1989–2012
SOURCE: European Patent Office (2013).
NOTE: According to this figure, the University of Cambridge has applied for patents on a growing basis since 1989.

TABLE 1.1 Incomes of the University of Cambridge, 2011–12

Funding source	*Annual income (thousands)*	*Percentage of total income*
Higher Education Funding Council for England and the Training and Development Agency for Schools grants	£197,265	23.5
Research grants and contracts	£293,441	34.9
Fee income	£149,234	17.7
Endowment and investment income	£54,383	6.5
Other income	£146,438	17.4
Total income	**£840,761**	

SOURCE: University of Cambridge (2013).
NOTE: Government funding for UK higher education has grown steadily since 1994. However, the level of funding per student has fallen dramatically.

biosciences. Table 1.1 shows data on the breakdown of the university's income; 24 percent is based on government funding, and another 35 percent is based on other funding for research grants and contracts.[5] It is interesting to note that total government funding for UK higher education has grown steadily since 1994. However, the level of funding per student has fallen dramatically. With the growth in the number of universities, the number of participating students grew. Thus, funding per university declined. This is the case with Cambridge, where the current endowment of £3 billion ($4.65 billion) is large compared to that of other UK universities but small when compared to that of Harvard, which has a $30.4 billion endowment, and Yale, which has $19.3 billion (Staley 2013).

In the academic year 2011–12, 57 percent of the University of Cambridge's students were in the sciences and 5 percent in the medical school (compared with 13 and 4 percent, respectively, at Yale).[6] Of the faculty, 35 percent are in science, and 3 percent are in the medical school (compared with 11 percent and 53 percent, respectively, at Yale), with a ratio of 6.3 students per faculty member in Cambridge (compared with 3 at Yale and 8 at MIT).[7] On the one hand, this ratio implies that Cambridge's faculty members have less time to invest in their students, work on their own research, and collaborate with other researchers or industries. On the other hand, this ratio exemplifies the importance of teaching to the university's culture. Cambridge is well known for its small-group teaching. Faculty are required to tutor students in small groups of two or three students at a time, which places even more teaching responsibilities on the faculty.

The University of Cambridge sees itself as a national and international university, not as a regional leader. O'Shea et al. (2005) argue that a university's history and resources influence its mission and organization, and also influence the university's knowledge-transfer capabilities. The organization's cultural base, influenced by the organization's history and the history of the decision makers in the organization, affects the way in which the organization makes decisions about issues such as strategy, outlook, and cooperation with other players in the local economy (Schoenberger 1997).

Thus, the fact that Cambridge does not see itself as a regional player influences the way in which the university engages and contributes to the local economy. Therefore, to encourage local academic entrepreneurship, there is a need for a commercially supportive culture at the university. The way Cambridge perceives itself is reflected in its mission "to contribute to Society through the pursuit of education, learning, and research." This also reflects the way in which the university structures university-industry relationships in general and technology transfer in particular.

Yale University

> Each college surrounds a courtyard and occupies up to a full city block, providing a congenial community where residents live, eat, socialize, and pursue a variety of academic and extracurricular activities. Each college has a master

and dean, as well as a number of resident faculty members known as fellows, and each has its own dining hall, library, seminar rooms, recreation lounges, and other facilities. (Yale University 2013)

Yale University is the third-oldest institution of higher learning in the United States. Yale was built in 1701 and was renamed Yale College in 1718 after Elihu Yale, who made significant donations to the college. In the 1930s Yale established residential colleges, similar to those at Oxford and the University of Cambridge. Its new model was a distinctive system that divided the undergraduate population into twelve separate communities of approximately 450 members each, allowing Yale to offer both the intimacy of a small college environment and the resources of a major research university. In fall 2011, there were 11,875 students at Yale, of which 17 percent were international students representing 118 countries.

Although Yale is known for its excellence in many fields, including life sciences, Yale University's historical culture of noninvolvement in the community in general and with industry in particular created a situation in which it failed to reap the credit for several important discoveries, such as the transgenic mouse.[8] For many years Yale was not active in technology commercialization, and by 1993 it had spun out only three biotechnology companies. This attitude of noninvolvement in industry changed during 1993–96. On the academic level, in 1994 Yale invested heavily in the life sciences. Out of a total of 729 tenured faculty members, 38 percent (279) taught in the medical school and another 5 percent (36) in the biological sciences (Office of Institutional Research 2001). According to Yale's 1995–96 financial report, income from research grants and contracts represented 29 percent of total income and totaled $262.2 million in fiscal year 1996. Of those funds, nearly 75 percent supported programs in the medical school and the Departments of Biological and Physical Sciences and Engineering. Of the $262.2 million, $203.6 million represented federal government funds, of which 80 percent was awarded by the National Institutes of Health.

However, Yale was a promoter neither of applicable research nor of working with industry. Hence, in 1994, Yale spent $224,939,000 on R&D but registered only sixteen patents. It is interesting to compare these figures with those of MIT, which spent $374,768,000 on R&D in that year and registered ninety-nine patents (National Science Foundation 2003). While Yale spent $14,058,388 per patent, MIT spent $3,785,535 per patent, a ratio almost four times higher for Yale. Also, by 1993, Yale had spun out just three biotech companies, compared with MIT, which had spun out thirty, and only one of Yale's spinouts, Alexion Pharmaceuticals, had stayed in the New Haven region. These figures are broadly consistent with the reputation of Yale at the time as an institution only peripherally and sporadically involved with the local economy and community. As Yale's president Richard Levin noted years later:

> 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. (Yale Office of Public Affairs 2003)

With the exception of faculty in a few departments, such as pharmacology, during this period, Yale faculty members were not encouraged to work on research with practical applications. It was actually implied that the outcome of such involvement would have an unfavorable impact on one's academic career. A former faculty member at Yale 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 that was not a good status" (interview with former Yale faculty member). So even though important discoveries were made at Yale during that period, the Office of Cooperative Research had a somewhat passive attitude toward commercialization, and only a few discoveries were patented.[9] According to another former faculty member:

> [There was] very little applied research in biology, maybe in the medical school or Pharmacology and Chemistry Departments. In the Biology Department it was looked down upon. For example, we made the first transgenic mouse, and [the Office of Cooperative Research] 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. (Interview with Yale faculty member)

Although only a few biotech firms established themselves prior to 1993, this was not the result of an inhospitable environment. In fact, by 1993, Connecticut had hosted five pharmaceutical companies: Pfizer, Bristol-Myers Squibb, Purdue, Bayer, and Boehringer Ingelheim. Most of these companies had a major presence in the state, including research facilities; four of these companies were 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 percent of the nation's total). The companies operated research-oriented facilities staffed with scientists with an intensive knowledge base in biomedicine, but interactions with researchers at Yale and other local universities were limited. None of these companies established institutional relationships with local research institutes, relying instead on opportunistic interactions between their investigators and individual researchers at the institutes.

In summary, when we examine these two universities, University of Cambridge and Yale University, we find that while they seem similar on many levels, they are different in their abilities to commercialize technology. We have a public versus private university, an institution that had a history of university-industry relationships and one that did not, one that has funding and allows faculty to focus on research and one that focuses on teaching and has limited research funding. This is the basis for the differentiation of the two universities, but it is also the basis from which we start our journey toward understanding the optimal formula for technology commercialization and knowledge transfer.

NEXT CHAPTERS

The book is organized as follows: Chapter 2 examines existing studies on university technology commercialization and organizational change, finding that current studies do not entirely explain the differences in universities' ability to commercialize technology. Chapter 3 explains the national framework in which each university has been operating, and in particular focuses on science and technology policy as well as on university system organization and funding in each country. Chapters 4 and 5 provide detailed overviews of the history and organizational change that both Cambridge and Yale experienced, including the role of the universities in the region before and after the changes. Specifically, these chapters provide a detailed explanation of the successful change at Yale University. The book concludes with three lessons. First, knowledge transfer and technology commercialization require the collaboration of many regional and national players. Second, historical and environmental factors have enormous, direct impact on the ability of an institution to commercialize technology. Third, intrauniversity factors, which are highly diverse, are the most important factors to consider in technology commercialization. This research adds three additional factors that affect successful technology commercialization in particular to universities that are trying to improve their technology-transfer process: the velocity of the university's organizational change in relation to commercialization, the level of the change within the university (partial or comprehensive), and the community of change (whether a change is done in collaboration with other players in the region).