ROUTLEDGE STUDIES IN GLOBAL COMPETITION

University Technology Transfer

The globalization of academic innovation

Edited by
Shiri M. Breznitz and Henry Etzkowitz

ROUTLEDGE

University Technology Transfer

Universities have become essential players in the generation of knowledge and innovation. Through the commercialization of technology, they have developed the ability to influence regional economic growth. By examining different commercialization models this book analyses technology transfer at universities as part of a national and regional system. It provides insight as to why certain models work better than others, and reaffirms that technology transfer programs must be linked to their regional and commercial environments.
Using a global perspective on technology commercialization, this book divides the discussion between developed and developing countries according to the level of university commercialization capability. Case studies examine policies and culture of university involvement in economic development, relationships between university and industry, and the commercialization of technology first developed at universities. In addition, each chapter provides examples from specific universities in each country from a regional, national and international comparative perspective.

This book will be highly relevant to all those with an interest in innovation studies, organizational studies, regional economics, higher education, public policy and business entrepreneurship.

Shiri M. Breznitz is Assistant Professor at the Munk School of Global Affairs at the University of Toronto, Canada.

Henry Etzkowitz is Senior Researcher at the Human Sciences and Technologies Advanced Research Institute, Stanford University, USA, and Visiting Professor at School of Management, Birkbeck College, London University and Edinburgh University Business School, UK.

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Contributors

Joaquín M. Azagra-Caro is a Tenured Scientist at INGENIO (CSIC-UPV), which is a joint research institute of the Spanish National Research Council (CSIC) and the Polytechnic University of Valencia (UPV), Spain.

Shiri M. Breznitz is an Assistant Professor at the Munk School of Global Affairs at the University of Toronto, Canada.

Elena Castro-Martínez is a Tenured Scientist working at INGENIO (CSIC-UPV), which is a joint research institute of the Spanish National Research Council (CSIC) and the Polytechnic University of Valencia (UPV), Spain.

Sabarni K. Chatterjee is a Senior Licensing and Patenting Manager at the Office of Technology Transfer, National Institutes of Health and Human Services, Rockville, MD. He is also the Deputy Regional Coordinator of the Federal Laboratory Consortium for Technology Transfer, Mid-Atlantic Region.

Paige Clayton is a Doctoral Student in the Department of Public Policy at the University of North Carolina, Chapel Hill, U.S.A.

Thiago J. C. C. Soares is a Researcher in the Technology and Innovation Management Group at the Federal University of São Paulo, Brazil.

Pablo D'Este is a Tenured Scientist at INGENIO (CSIC-UPV), which is a joint research institute of the Spanish National Research Council (CSIC) and the Polytechnic University of Valencia (UPV), Spain.

Henry Etzkowitz is President of the Triple Helix Association; Editor-in-Chief of *Triple Helix* (a journal of university–industry–government innovation and entrepreneurship); and author of the book *The Triple Helix* (Routledge 2008). He is also Visiting Professor Birkbeck and University of London, and Advisor to the Shandong Academy of Sciences, P.R. China.

Claudio Fassio is a Post-Doctorate fellow at the School of European Political Economy (SEP), LUISS Guido Carli, Rome, and research fellow at BRICK, Collegio Carlo Alberto, Italy.

Maryann Feldman is the Heninger Distinguished Professor in the Department of Public Policy at the University of North Carolina, Chapel Hill and Program Director at Science of Science and Innovation Policy (SciSIP) at the National Science Foundation (NSF), U.S.A.

Ignacio Fernández de Lucio is Research Professor at the Spanish Council for Scientific Research (CSIC) working on INGENIO (CSIC-UPV), which is a joint research institute of the Spanish National Research Council (CSIC) and the Polytechnic University of Valencia (UPV), Spain.

Ciara Fitzgerald is a Lecturer in the Department of Accounting, Finance and Information Systems at the University College Dublin, Ireland.

Adela García-Aracil is a Tenured Scientist of CSIC at INGENIO), which is a joint research institute of the Spanish National Research Council (CSIC) and the Polytechnic University of Valencia (UPV), Spain.

Christiane Gebhardt is the Vice President Head Global Initiatives at Malik Management Institute in St. Gallen, Switzerland.

Lodewijk L. Gelauff is Project Manager at ScienceWorks in The Hague, Netherlands.

Aldo Geuna is Full Professor at the Department of Economics and Statistics Cognetti De Martiis, University of Torino and Fellow of the Collegio Carlo Alberto, Italy.

John Glasson is Professor Emeritus of Planning in the Department of Planning, Oxford Brookes University, U.K.

Devrim Göktepe-Hultén is an Assistant Professor at the Department of Business Administration, Lund University, Sweden.

Nicola Hepburn is Manager, Policy & Research at a major financial institution in Toronto, Canada.

Jonathan J. Jensen is a Senior Licensing Manager at Partners HealthCare, Boston, MA, U.S.A.

Martin Kenney is a Professor in Community and Regional Development in the College of Agriculture and Environmental Sciences at the University of California, Davis (U.S.A.); a Senior Project Director at the Berkeley Roundtable on the International Economy; and Senior Fellow at the Research Institute for the Finnish Economy, Helsinki, Finland.

Patrick C. Kilgore is a registered patent attorney in private practice in Chicago, Illinois, focusing on representing clients in patent litigation concerning small molecule and biologic pharmaceuticals.

Helen Lawton Smith is Professor of Entrepreneurship, Department of Management, Birkbeck, and University of London, U.K.

Eric London is Senior Director at W.L. Ross & Co. LLC in New York, NY, U.S.A.

Lita Nelsen is the Director of the Technology Licensing Office M.I.T., Cambridge, MA, U.S.A.

Tran Ngoc Ca is Director of Secretariat for the National Council for Science and Technology Policy, Personal Assistant to S&T Minister and Deputy Director, National Institute for Science and Technology Policy and Strategy Studies, Hanoi, Vietnam.

Rory P. O'Shea is a faculty member at the University College Dublin (UCD) School of Business, Ireland.

Donald Patton is a research associate with Community and Regional Development at the University of California, Davis, U.S.A.

Guilherme Ary Plonski is a Professor at the University of São Paulo (USP; Brazil). He is affiliated with both the Business School and the Engineering School, and is the Research Director of the Center for Technology Policy and Management.

Tatiana Pospelova is a PhD student at the School of Economics, Lomonosov Moscow State University, Russia.

M. Elizabeth R. dos Santos is Head of the Technology Transfer Office of the Pontifical Catholic University of Rio Grande do Sul (PUCRS), Brazil.

Mark L. Rohrbaugh is Special Advisor for Technology Transfer, Office of the Director, National Institutes of Health, Department of Health and Human Services, Bethesda, MD, U.S.A.

Federica Rossi is Lecturer at the Department of Management, Birkbeck, University of London, U.K.

Ashley J. Stevens is a Lecturer at Boston University's Strategy and Innovation Department, School of Management, Boston, MA, U.S.A. and is also President of Focus IP Group, an IP consulting company. Previously, he was Director of the Office of Technology Transfer of Boston University and Director of the Office of Technology Transfer of the Dana-Farber Cancer Institute, a teaching affiliate of the Harvard Medical School, U.S.A.

Robert J.W. Tijssen is Professor at Leiden University (Netherlands), Stellenbosch University (South Africa) and one of U-Multirank's project managers.

Ana L. V. Torkomian is a Professor in the Department of Production Engineering, Federal University of São Carlos (DEP/UFSCar), Brazil.

David A. Wolfe is Professor of Political Science at UTM and Co-Director of the Innovation Policy Lab at the Munk School of Global Affairs in Toronto, Canada.

Jarunee Wonglimpiyarat is a Member in the College of Innovation, Thammasat University, Thailand.

Katrine Wyller works with early phase governmental support for business development at the Research Council of Norway, Oslo.

Qingzhi Zhang is an Assistant Professor at the University of the Chinese Academy of Sciences, Beijing, P.R. China.

Chunyan Zhou is the Director and senior researcher for the International Triple Helix Institute (ITHI), U.S.A. She is also the Co-Director and leading researcher for the Regional Innovation & Entrepreneurship Center at Shandong Academy of Science, P.R. China.

Frank J.M. Zwetsloot is CEO of ScienceWorks, The Hague, Netherlands.

Part I

Introduction

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1 The evolution of technology transfer

Henry Etzkowitz

Three questions

Why do universities transfer technology? Is not technology transfer a business far removed from traditional academic missions of education and research? Nevertheless, how did interface between academia and industry become an academic pursuit, despite divergent institutional logics? Evolving from an informal professorial avocation to a professional administrative office and from a legal to marketing to an entrepreneurial approach, technology transfer has spread across academia. As the transfer of technology has shifted from marginal to mainstream, a host of questions have been raised over the purpose of the university, the nature of knowledge and the role of the university in society. Serendipitous discoveries, whose beneficial consequences also subjected the university and populace to risk, drove the initial direction of policy discourse.

The origins of formal university technology transfer may not surprisingly be traced to events at the University of Wisconsin, a land grant school with a practical orientation strongly focused on the state's agricultural dairy industry and more intriguingly to the University of Toronto, a liberal arts research university whose practical orientation was largely confined to its medical school where research was carried out to cure disease. A successful diabetes research project generated significant intellectual property in the early twentieth century (Bliss 1982). Both cases generated issues of ethical manufacture that required formal intellectual property protection to resolve (Apple 1989). In subsequent decades, the economic spillover from early instances of university technology transfer moved front and center as a significant, if not primary, motivation for stakeholders, inside and outside of academia. These developments have raised fundamental epistemological, ethical and normative issues.

In the Faust legend there is a bargain with the devil and an exchange of a soul for arcane, highly desired, knowledge. Some critics argue that the university has made a similar arrangement by involving itself in technology transfer in the first place (Washburn 2005). In the following sections we discuss the expansion of technology transfer from its traditional meaning of movement across national borders (still an important and even primary mode in many countries) to movement among units within and among firms and between university and industry. The rise of university technology transfer is part of a second academic revolution, making contribution to economic and social development an accepted academic mission that is interwoven with education and research.

Technology transfer and the academic mission

Extending beyond well-accepted service tasks, technology transfer is conventionally viewed as an expression of the so-called linear model, proceeding from research to invention and innovation (Bush 1945). However, technology transfer may also be viewed within a broader non-linear framework that also includes feedback mechanisms proceeding from societal needs and invention back to blue sky research. The supposedly discrete categories of basic and applied research, never watertight, with handovers between them along a linear path, are superseded by "polyvalent knowledge" with theoretical and practical implications inherent in the same research finding. In a classic instance of polyvalence, agricultural researchers at U.S. land grant universities in the 1930s discovered hybrid corn by extending their government funded research programs, designed to solve immediate crop problems, to address fundamental questions in genetics (Griliches 1960).

The inclusion of technology transfer in the academic mission is part of a broader paradigm shift from a research to an entrepreneurial academic mode superseding the dyadic Humboldtian paradigm, combining research and education. However, research and a mindset to translate research into practice, if not personal economic reward, is the prerequisite to technology transfer Research was typically an add-on to the classical academic mission of education that included preservation and dissemination of high culture and training for legal, ecclesiastical and medical professions. A research mission, however, is a prerequisite to a technology transfer mission, if not an entrepreneurial remit that can be built upon a teaching as well as a research base.

Most important to academics: students, faculty and administrators and university stakeholders is the question of which academic model to follow: the now traditional research university model, focused on education and research, with technology transfer and innovation an adjunct activity or an emerging entrepreneurial university model in which the two academic missions that converged into an integrated format in the late nineteenth century are joined with a third mission of contribution to economic and social development that is of equal status. The dual Humboldtian paradigm is transmogrifying into a Triple Helix University, paradoxically both more closely linked to industry and government, while expanding its independence as a more salient institutional sphere (Etzkowitz 2008).

The choice between the research and entrepreneurial models suggests different roles and status for technology transfer in the university. Answers to the following questions will indicate preference for one model or the other: Should academic knowledge be conceptualized as a meandering stream of fundamental research from which practical implications emerge as an occasional serendipitous byproduct? Or has a normative revolution occurred in which polyvalent knowledge, with simultaneous theoretical and practical import, publishable and patentable attributes? Spin-offs may be generated and discoveries are disseminated in the media as well as academic journals. Heretofore, between discovery and utilization one or two generations intervened whereas more recently these phenomena occur within the same generation, simultaneously or even in reverse order.

Pasteur's Quadrant denotes research that is of both theoretical and practical import (Stokes 1997). It is accompanied by two additional eponomyzed quadrants, Edison and Bohr representing each side of a traditional theoretical practical divide. However, Indeed, the exemplary exponents of these quadrants Niels Bohr and Thomas Edison do not entirely fit their respective quadrants. Bohr took the practical consequences of research in nuclear physics into account and lobbied politicians to influence its utilization. Edison, the consummate "cut and try" inventor was also the discoverer of the "Edison effect."

In contrast to the concept of Pasteur's Quadrant in which basic knowledge with practical implications is confined to a delimited sphere, we expect polyvalent knowledge to envelop the traditional quadrants of basic and applied research. Researchers may pursue a variety of crosscutting objectives simultaneously rather than operating according to either/or motivations that separate advancement of fundamental understanding from solution of practical problems.

Second, the polyvalent knowledge position indicates that transfer should be embedded in the educational and research missions as well as vice versa, with incubators as well as labs an integral part of academic physical structures, with representatives of transfer offices present at research group meetings to identify potential IP and technology transfer part of the academic degree program as well as economic development mission.

Third, the Pastuer's quadrant model suggests that various formats of knowledge production and utilization may co-exist peacefully, likely located in different parts of the university, with the engineering and medical schools taking a polyvalent approach while the arts and sciences follow the meandering stream. These theoretical perspectives have implications for the course and direction as well as location, of technology transfer in an academic setting. First, the meandering stream position suggests that technology transfer should be carried out in isolation from education and research, with technology transfer professionals available to assist transfer of inventions disclosed to them but that they not take a pro-active stance to suggest lines of investigation out of concern that such steering would violate the purity of academic knowledge.

The nature of knowledge is also at issue. If a constructivist position is taken science is seen as socially shaped with knowledge claims malleable and subject to social control. On the other hand, if scientific knowledge is viewed as containing an irreducible empirical core that social factors to not influence, then alternative policy implications may be drawn. Social factors may drive topic selection, influence perception and non-perception of results, e.g. difficulties anomalies have in disrupting paradigms. Thus, recognition of a discovery may lag until a build-up of results or the passing of adherents (Kuhn 1962, Ventner 2013).

Nevertheless, social factors do not ultimately determine the nature of scientific knowledge. They explain as much as 75% of variance but there is an irreducible empirical core (Fleck [1935] 1976). Indeed, attempts to produce fraudulent knowledge claims will be more quickly discovered if they are expected to produce commercializable results as well. A pragmatic test of the claims will quickly ensue and the validity will be ascertained. On the other hand, most academic papers are not read, let alone cited and a fraudulent paper may reside in the scientific literature indefinitely, while still driving tenure and promotion decisions. Thus university technology transfer has become central to debates over academic mission, the nature of the science and innovation.

Technology transfer and innovation

Technology transfer is the movement of particular inventions, entire technological systems or knowledge of how to construct them across national or organizational boundaries. The processes of technology transfer have been noted to occur across time and space, during the medieval period in the diffusion of such basic technologies as the waterwheel, windmill and heavy plough, and in the relations among civilizations such as China and the West, in which both organizational technologies such as bureaucracy and physical technologies such as gunpowder moved westward. Technology transfer is a key element of economic growth, perhaps even more important than the invention and development of technology.

Technology transfer is a complex process that requires appropriate organizational and cultural "software" as well as technical "hardware" to be accomplished in its most productive form. More than the relocation of a physical artifact, technology transfer also involves entrepreneurship, specific skills, even government finance or patronage as well as commercial demand. According to Misa (1995) technology transfer, in its most developed form, is the ability to obtain knowledge and skills from an originating source, adapt them to use in a different economic and social structure and then diffuse them into new technical applications in other industrial sectors.

Equal partners freely entering into agreements, the contemporary positive image of technology transfer has a reverse mirror image. Headrick (1988) shows how colonial powers have used technology transfer as a means to increase their economic and political influence, without necessarily having to use military force. In this inherently unequal patron/client relationship the "sender" typically restricted the transfer process to a narrow domain and limited access to the knowledge transferred by having its nationals operate the relocated technology. For example, British engineers operated locomotives for as long as three-quarters of a century after the construction of the first railroad in India, keeping this skill out of the hands of the "receivers" for as long as possible.

The purpose of colonial technology transfer was to draw the less developed country more fully into the colonizer's economic and political orbit. Thus, colonizers in India and Africa put transportation technologies, such as rail and road, in place to assist in the extraction of resources and the movement of troops.

Communication technologies such as telegraph and telephone systems were installed to help a few colonial administrators maintain political control over vast regions and large populations. Nevertheless, once installed these technologies became a double-edged sword, used by indigenous peoples for their own purposes, including creation of networks and organizations to displace their colonial rulers. When Tata built steel mills with technology imported from the U.S.: British officials viewed them as a bulwark of empire while nationalist Indian entrepreneurs saw the groundwork for an independent economy.

After independence, technology transfer as an economic development strategy becomes clear to both sides, as the former colonizer and newly independent nation, struggle to assert their opposing interests. David (1981) delineates the workings of this process as overall favorable to the emerging nation, at least in the growth of the U.S. textile in the early nineteenth century. American manufacturers sought to obtain knowledge and devices from Britain through socially mobile individuals willing to leave their home country and recreate devices upon their arrival in the U.S. Although it could not prevent the movement of technology the British government was able to exact an additional cost on its transfer through export and immigration controls.

On the U.S. side, technology transfer was facilitated and magnified by the availability of technologically knowledgeable individuals who adapted the technology to local circumstances. Knowledge embodied in persons, whether laborers or factory owners, was far more important to successful transfer of technology than the artifacts themselves. In this analysis particular bits of technology were moved by specific individuals across national boundaries within the same industrial sector.

David's (1981) case study of textile technology exemplifies Inkster's category of narrow technology transfer. In this mode a particular technology is transferred from its place of origin as a technological process in a particular industry to another geographical site within the same industrial context. On the other hand, in broad technology transfer a technology is moved from its place of origin to a variety of applications across several industries. For the latter to be more likely to take place a local R&D capacity is required.

What are the preconditions for successful technology transfer? Landes (1972) emphasizes conditions at the receptor site as a prerequisite for successful technology transfer: the importance of a stable political and legal environment, with reliable contracts replacing force as the guarantor of relationships. Tar and Dupuy (1988) also emphasize the importance of the unique physical, economic and social context into which technology is transferred. If technology is not appropriately modified to fit local circumstances it may well fail to take hold. Thus, British "destructor" technology for incinerating urban wastes that was economical in a dense urban setting, where even outlying land was too costly to be devoted to a dump, worked less well in the U.S. in the late nineteenth and early twentieth centuries, where burying wastes was a viable alternative.

There are fascinating anomalies in technology transfer. The movement of technology across national borders has been found to be more rapid than diffusion within them. For example, Watt's steam engine patented in Britain in 1776, came into use in France in 1779 and Germany in 1788, yet its use was not widespread until the 1830s and 40s. Kenwood and Lougheed's (1982) finding suggests the salience of regional disparities to the potential for technology transfer and the greater likelihood for transfer among "high-tech" areas, wherever they are located. Tod (1995) focuses on the question: Can technology transfer generate a capacity for innovation (in the Australian context)? The answer is at least in part dependent upon the ability to move newly acquired technical capabilities more broadly across the economy.

With the decline of colonialism and protectionism technology transfer has taken on a new meaning, denoting the movement of technology across institutional spheres such as between academia and industry (Gibbons et al. 1994). Beginning with the contractual sale of specific pieces of intellectual property between firms, technology transfer becomes a way of integrating inventors and manufacturers, producers and users of technology. Beyond a unidirectional flow of rights to artifacts between organizations in different places, technology transfer can grow into a two-way flow of ideas and techniques among a variety of partners who may come to see themselves as participants in a virtual joint enterprise. Alternatively, universities and their faculty may become adversaries in tough negotiations and find themselves, on opposite sides of court battles over patents as in Madey v. Duke in which a university claimed the intellectual property rights of a faculty member, including rights generated while employed at another university.

The sources of university technology transfer

Entrepreneurs hanging around MIT's laboratories, acting like vultures by seeking commercializable technology to take without recompense, inspired the university to protect its intellectual property. University technology transfer originated at MIT in the form of a joint faculty/administration committee to evaluate inventions and encourage their protection and development. Faculty can reasonably extend their professional capacities to evaluate the commercial potential of colleagues' research, especially if they have participated in spin-off creation, but protection of IP requires specialized legal expertise that if carried out by a university requires a home. Thus, the technology transfer office (TTO) was invented at the University of Wisconsin, first in the form of a foundation, a quasi-independent organization, to establish distance from traditional academic missions,

Teachers with only limited formal higher training early laid the groundwork for informal technology transfer. Alexander Graham Bell, whose training in audiology largely occurred within an intergenerational "family business" of teaching the deaf, for example, developed the telephone as a teacher at Boston University, in facilities provided by the university receiving release time from teaching to carry out the project and spun out a firm. On the other hand, Princeton physicist Joseph Henry, who had worked out the theory of the invention of the telegraph felt inhibited from taking the next steps to reduce his ideas to practice. From his later vantage point as the Director of the Smithsonian Institution, having missed out on the invention of the telegraph, he ruefully advised Bell not to make the same mistake with telephony (Moyer 1997).

A special class of institutions of higher learning—the so-called land grant universities in the U.S., e.g. University of Connecticut and MIT, and polytechnic universities in Europe, ETH Zurich and Polytechnico Milan—focused on supporting regional mechanical and agricultural industries (Artz 1966, Rossiter 1975). This practical orientation spread to a broader group of universities, hybrids of the polytechnic/land grant mode and the liberal arts College, New York University, focused on commerce, and Stanford on engineering are prototypical examples of universities that combine practical with theoretical academic pursuits. MIT expanded its purview into the humanities and social sciences to facilitate students ascent to corporate leadership positions that might otherwise be occupied by Harvard graduates whose liberal arts curriculum was presumed to better prepare them for leadership.

There are multiple pathways to an entrepreneurial academic mode. Entrepreneurial universities have arisen from diverse academic traditions. MIT derived an entrepreneurial academic model from a synthesis of the U.S. Land Grant and European Polytechnic traditions. Nevertheless, MIT also incorporated specific elements of the liberal arts tradition in order to give its technical students a broader purview. Stanford, like New York University, originated as a synthesis of the liberal arts university tradition and a private university model oriented respectively to technological and commercial local economic development. The Pontifical Catholic University of Rio de Janeiro took an entrepreneurial turn in the face of loss of research funding from Brazil's former military regime. At many universities, an entrepreneurial initiative is encapsulated in a particular organizational mechanism like an incubator facility or TTO that, at least initially, is segregated from the rest of the university.

A technology transfer regime may be instituted directly by a national government, as in Japan, through a funding program replete with benchmarks and qualification procedures, or indirectly as in the U.S., through legal changes incentivizing universities to develop transfer capabilities. The Amendment to U.S. patent law of 1980, better known eponymously after its sponsors Senators Birch Bayh and Robert Dole, gave universities ownership of intellectual property rights to federally funded research, an explicit role in technology transfer and included inventors in the reward scheme (Stevens 2004).

Heretofore uninterested universities established a TTO, showing an interest in putting research to use and thus meeting the criteria for continued receipt of federal research funding. Despite low expectations these new offices sometimes achieved a highly successful patent, as at Columbia University, thus gaining support of the university's administration for expansion of their activities. Other offices, less lucky or lacking a prolific faculty adopted a "pump priming" strategy, encouraging researchers to explore the commercial potential of their research (Etzkowitz and Goktepe 2010). In yet other cases, offices remained dormant (Feldman and Desrochers 2004) until reorganized, for example, as part of a strategy to develop a biotech industry next to Johns Hopkins University.

Integrating the transfer process in an entrepreneurial academic culture has become a virtually universal goal in divergent academic systems. Organizational capabilities are enhanced in systems that leave intellectual property rights in the hands of the inventor as in “the Professor’s exemption” in Sweden. Following medieval European practice the professoriate was exempt from many of the obligations of the ordinary citizen, like the requirement to quarter soldiers in ones house in times of emergency and were also sometimes entitled to special emoluments such as public provision of wine. Similarly professors were allowed to retain control of the intellectual property that they generated during their university employment. Thus Swedish tech transfer office negotiates with faculty to gain the rights to their discoveries for purposes of commercialization. Faculties are not required to disclose. On the other hand, the office has the ability to offer support such as covering patent fees and otherwise supporting research commercialization as an incentive for faculty to wish the university’s participation. The Bayh-Dole Act of 1980 laid the groundwork for universities to construct policies that encourage professors to treat disclosure of intellectual property as the quid pro quo for receiving federal research funds.

Differences are often less than perceived as the U.S. system guarantees the faculty member a significant share of the results, in contrast to corporate inventors who are entirely dependent upon the generosity of their employers to receive anything beyond a commendation or possibly a promotion but not a direct share of profits from their invention. The U.S. Bayh-Dole Act, in effect, created a “partial professor’s privilege,” guaranteeing university inventors a significant share of rewards in contrast to firm employees, dependent upon employer’s generosity. Thus, the inventor is granted a significant interest even as formal rights are placed under the control of the university. In the former instance, the university may negotiate to acquire intellectual property rights; in the latter, the university is strongly dependent upon inventor cooperation to realize value from formal rights.

Tech transfer: legal mode

The legal format is characterized by the university’s recognition of the necessity to patent in order to protect the university’s reputation and ensure user safety, was recognized at Toronto and Wisconsin, respectively, through the insulin and milk purity test experiences (Bliss 1984, Apple 1989). A marketing format transformed the arm’s length intellectual property protection approach into a more pro-active regime in which the university actively sought out prospective licensees, beyond the purview of the inventor. This phase included brainstorming to simultaneously extend patent claims and identify additional markets. Entrepreneurial faculty at Stanford and MIT translated inventions into firms before the development of formal technology transfer. Aspiring schools created an incubation and entrepreneurial training process designed to replicate, in a collapsed time frame, the early informal developments at Stanford and MIT (Hatakenaka 2004).

These evolutionary phases are also instantiated in actually existing TTO's as their institutional logics. Thus a TTO, typically led by an attorney, may follow the legal approach, protecting the discoveries but making little effort to actively seek out licensees beyond the basic announcement on the TTO's website. The marketing model is the next step, with the TTO making an active effort to seek out potential licensees by developing and extending relationships in industry, especially those relevant to its main source of inventors. The following step is an entrepreneurial approach in which the TTO actively support the formation of a firm, providing entrepreneurial talent and even financing to support the early stages of firm formation. At this point the TTO typically becomes part of a broader innovation unit within the universities, supporting a variety of entrepreneurial activities that include but extend beyond technology transfer

University technology transfer in the U.S. innovation system

The theoretical framework for U.S. technology transfer was created in the context of the Second World War when basic researchers combined forces with engineers to produce new weapons as an extension of basic research (e.g. the atomic bomb) as well as from military requirements to detect hostile aircraft (e.g. radar). Although the scientists expected that they were putting aside their theoretical pursuits for the duration of the wartime emergency they found, to their surprise, that new ideas for investigation were arising from their involvement with practical problems.

The efflorescence of theory from practice was a phenomenon earlier noted by a young engineering professor at MIT, Vannevar Bush, who brought back ideas from his consulting practice for elucidation with his students. Later, as a high level wartime science and technology administrator, looking towards peacetime and operating in an ideological environment in which a role for government is highly suspect (cf. the recent U.S. health care debate), Bush disentangled science from its social context and placed it on a metaphorical plane to attain his broader objective: government support of research for a variety of purposes in the post-war, superseding the narrower wartime focus that had provided temporary large-scale funding for scientific research (Baxter 1946).

Bush's post-war linear model is the partial revival of the wartime non-linear "triple helix" that the U.S. has since more fully recuperated through the Bayh-Dole Act and other measures. In the "game of legitimation" that Bush was playing, he had to, with one hand, place research on a neutral ground ("the frontier") while with the other, execute a sleight of hand and link its benefits back to the housing, military, health and other impetuses to research with practical goals that each received their special chapter in the Endless Frontier Report (Bush 1945).

A "linear model" served that purpose well although Bush was likely not a believer and certainly not a practitioner of linearity (Balconi, Brusoni and Orsenigo 2009). Vannevar Bush was an engineer, consultant, entrepreneur, teacher and researcher, in other words, the prototypical MIT professor. Bush was a student of the "consulting engineers" who had been recruited to MIT to introduce research in the late nineteenth and early twentieth centuries. They also brought their consulting practices with them into academe and synthesized a new academic entrepreneurial model (Etzkowitz 2002). As noted earlier, Bush made a practice of bringing back to his MIT graduate students theoretical issues arising from his industrial consulting projects and working them out together (Bush 1970).

One of these students was Fred Terman, who brought the model back with him to Stanford as a young professor where he expanded upon it in his own work, with students such as Hewlett and Packard, and later as an academic administrator in forming new research groups and then departments with conjoint theoretical and practical objectives. Bush and Terman are implicit exponents of "polyvalent knowledge" that is simultaneously theoretical and practical, publishable and patentable, rather than flowing through a constricted linear pipeline. Bush made a step-change in the academic entrepreneurial model, in the run-up to the Second World War, when he went to Washington D.C. to head the Carnegie Institution and led an effort that gave academia a central place in wartime research, with industry and the military. Academic scientists, especially those who led these labs, lost their fear of government funding, as inevitably leading to government control of science. Wartime experience in a collaborative leadership role, with industry and government, provided grounds for acceptance of state research support and an entrepreneurial role for the university in society as the engine of innovation, the implicit thrust of the Endless Frontier Report.

Government has since found it necessary to revise its role and play a more active part "downstream," by crafting innovation policies and programs to insure that research results, however generated, are actually put into practice. Indeed, even in a country with multiple research agencies like the U.S., this has been the approach as NSF's remit was extended into engineering and then to the provision of public venture capital (Etzkowitz, Gulbrandsen and Levitt 2000). Behind the laissez-faire presumption of the linear model that academic research results would seamlessly pass to industry through graduated students taking employment and industrial researchers following the journal literature, a more focused organizational approach to technology transfer, utilizing the patent system, had grown from its origins at MIT in the early twentieth century According to a university official, "The national innovation strategy is to put federally funded R&D on a conveyer belt that gets the R&D commercialized either by tech transfer to established companies or by wrapping the R&D into a university start-up…"[1]

Technology transfer and regional absorptive capacity

The confluence between public benefit and revenue models focuses attention on the region surrounding the university. A TTO director said that, "our mission is to promote technology to benefit the public; to the extent it results in revenue it is a good thing." In a region without previous high tech development, the TTO director may be the first person with an official responsibility for this topic. Even though his or her remit is focused on the university, an entrepreneurial director will soon expand it to include helping create the conditions for high-tech development in the area. Once local economic development considerations are taken into account, the issue broadens from the difficult enough one of finding a licensee to one of identifying a local source to develop the technology.

As one director put it, the objective is “to not just license technology but to capture and keep it in … [the state].” A TTO director in a peripheral region said that, “We now have a situation where faculty can do pre-incubation in their labs, we lease them space and sublicense equipment. The next step is either have a research bay or small lab that their company can rent and then graduate them out to incubator and other facilities run by the community.” Another director described various sources of funding to explore commercial potential, including the university’s own resources, “a small internal fund that can fund projects like that 50k per project” as well as external sources such as angel and state government funding.

In contrast to firm absorptive capacity that is held to be a function of prior related knowledge (Cohen and Levinthal 1990), developing regional absorptive capacity often entails breaking with previous practice (Saxenian 1994, Huffman and Quigley 2002). Regional absorptive capacity is operationalized as an entrepreneurial support structure of angel networks, venture capital opportunities, public relations and law firms oriented to support firm formation and cluster development but may take various forms. (Cooke 2001, Norrman 2005). Stanford faculty and students had the advantage not only of the location of largest proportion of the U.S. venture capital industry adjacent to the campus but also of colleagues with earnings from their previous ventures who could also afford to invest, as MIT entrepreneurs had long done.

On the other hand, when capacities are weak, new organizational formats may be invented such as the venture firm in early post-war New England or the “Courtyard for Agro-experts” in contemporary China (Tu, Gu and Wu 2005). In a region lacking a university, regional authorities developed a model of joint living and lab spaces to allow academics to visit for a limited time period, conduct research and consult on local agricultural problems.

University technology transfer must adapt to regional circumstances. A relatively low-key approach can work in a “thick” region, with strong entrepreneurial support capabilities while a more pro-active approach is indicated in a “thin” region, where absorptive capacity is weak. In the latter case, a TTO may take a leadership role to promote the creation of an external support structure and may also have to fill internal gaps when inventor interest is limited. Conversely an office may take a relatively passive stance when regional absorptive capacity and inventor interest is strong. However, this may result in untapped potential among moderately entrepreneurially oriented faculty, suggesting the applicability of support structures that are commonplace in aspiring universities to success cases as well.

The technology transfer gap has been filled by measures offering varying types and levels of support. Two approaches are typical: (1) intensified search to enhance the disclosure rate; and (2) entrepreneurial assistance to improve innovation chances. A half-time position in technology transfer and an academic department has been instituted in the Columbia University Medical School as a unique arrangement for an individual faculty member. This "dual-life" scheme formalized the "scouting function" of ARD, the original venture capital firm that served as an informal TTO and incubator for MIT in the early post-war. A serial entrepreneur, working at Stanford's Office of Technology Licensing (OTL) as a part-time licensing officer in between start-ups, frustrated with the paucity of licensing opportunities for a technology that he strongly believed in, formed a firm with special permission.

This "one-off" instance of a de-facto "entrepreneur in residence program" may regularly be found in Swedish university incubators. The two modes may also be combined. Thus, the "Chalmers Innovation System" includes a masters program in innovation and entrepreneurship to which student teams apply with commercialization ideas that they often source in academic research groups (Jacob et al. 2003). A Swedish hospital encourages nurses to be aware of the commercialization potential of devices they have invented and pairs them with "idea Pilots" and advisors to speed the innovation process (Nählinder 2010).

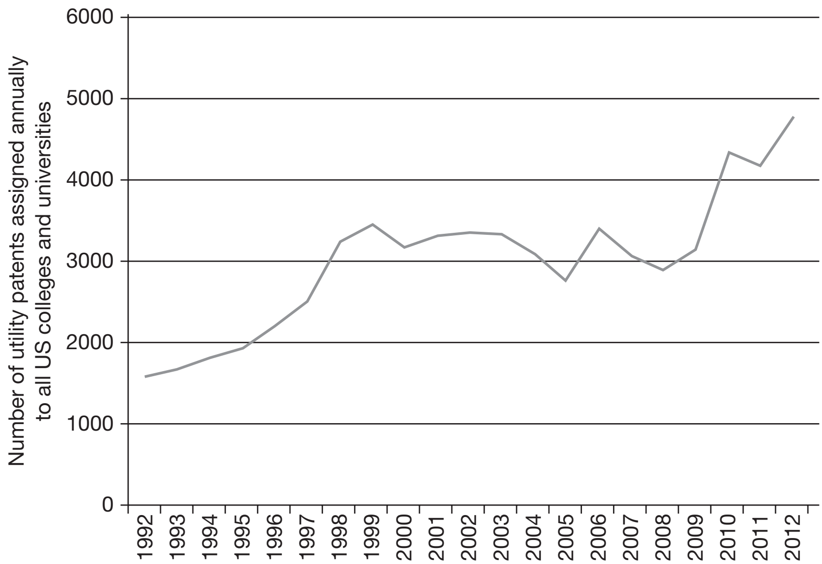
These experiments may be synthesized into an intensive transfer regime, to encourage a higher proportion of staff to become involved, including those not traditionally thought of as innovators, as well as raise the innovation rate. Aspiring schools typically view institutions they wish to emulate after success has already been achieved. They view the current policies, arrangements and procedures in place and assume that their replication will induce a similar result in their own institutions. However, what has been worked out at this later time may not be appropriate to an initiation phase. In the early stages of developing technology transfer, aggressive steps were taken. In a mature phase, once successful relations were developed, policies mandated strong boundaries. In an earlier era a Stanford administrator noted that it was, "not uncommon for a post-doc working in a Stanford lab to be spending a couple of days a week at a faculty start-up before it dawned that this was not consistent with the basic principles of the institution. What we are trying to avoid is the kinds of connections between a Stanford faculty member's academic program, resources, facilities, people and their outside entity. We are trying to keep a barrier between those."

The director of technology transfer at MIT, Lita Nelson, states that there is a "Chinese Wall" between academia and industry at her university strict rules are in place forbidding faculty members from playing an active role in firm formation. Decades earlier, the original venture capital firm, ARD, used underutilized space at MIT as an "incubator" for the firms that it was assisting MIT faculty members to establish. Currently, it is said that Ms Nelson merely turns the next card on her Rolodex to notify an area venture capitalist of the latest campus invention with start-up potential. The paradox is that if an aspiring entrepreneurial university adopts Stanford's and MIT's current practices, it may impede their chances of success. The precursor era of a success case is likely more relevant to the current situation of a follow-on region. Moreover, the best practices of an aspiring entrepreneurial university may be relevant to improving the practice of an international success case. In between mind and market, lab and Wall Street (or the City), a "permeable zone" emerges where two cultures intermingle (Kohler 2002:11).

A panoply of organizational hybrids to transfer scientific projects with economic potential have been invented such as incubator facilities, venture capital firms, science parks and TTOs. Many persons who work in these venues embody qualities drawn from both cultures. A meta-innovation system comprising bottom up, top down and lateral initiatives, from university, industry and government, individually and collectively, increasingly translates research into use and foster social as well as technological innovation (Etzkowitz et al. 2005).

The future of university technology transfer

Does this pecuniary interest in research represent a fundamental mission shift or is it a temporary aberration? It has been suggested that interest in intellectual property rights is receding and that universities are recovering from their "corporate fling" and returning to traditional tasks, motivated by international rating schemes that privilege article production. On the basis of a few years' modest downturn in the Association of University Technology Managers (AUTM) survey of U.S. academic patenting and cognate data, Leydesdorff and Meyer (2010) concluded that the end of university tech transfer is nigh. They drew this inference without seriously considering alternative explanations for a down-tick such as tighter criteria for patenting—e.g. protecting only what is identified as commercializable in advance rather than patenting in the expectation that a future



Source: USPTO official website: www.uspto.gov/web/offices/ac/ido/oeip/taf/univ/org_gr/all_univ_ag.htm

Figure 1.1 Number of utility patents assigned annually, to all U.S. colleges and universities pecuniary use may be identified. The U.K., on the other hand, showed a continuous up-tick (Lawton-Smith 2014). Indeed, the most recent AUTM survey data has shown an uptick in university patenting, continuing a two-year trend suggesting that, with U.S. academic patenting on the rise again, the downturn was only a temporary blip.[2] The slowdown and leveling off of U.S. university patenting, prematurely interpreted as the end of the Bayh-Dole era was disconfirmed as university patenting resumed its steady rise.

Others note a general slowdown in patenting as an artifact of changes in U.S. PTO practice and personnel to process applications. The institution of a preliminary patenting procedure, allowing a year of protection to explore the viability of a full application, has allowed offices to be more selective in their patent applications. Perhaps more significant is the continuing rise of university originated start-ups (AUTM 2010) and the expansion of technology transfer to an integrated model that supplies faculty inventors with entrepreneurial partners and seed funding from internal university resources, in effect, packaging start-ups (Tedeschi 2010). In any event, patents are, at best, an indirect proxy for commercialization of university research, as many sit on the shelf, or website, of their TTO while other innovations rely on trade secrecy for protection and may never be disclosed.

Even in a highly academic science oriented firm like Cetus, Kary Mullis, the inventor of polymerase, a major biotechnology innovation, received a payment of only $10,000. On the other hand, he received broader rewards as part of his employment contract (Rabinow 1997) signify regime change from a marketing to entrepreneurial mode of technology transfer in which patenting is a significant but less important part of university technology transfer success than firm formation and growth. Or, it may simply be an artifact of resource stringency induced by the Great Recession of 2008 in which case we may expect an uptick as its effects recede.

Rather than a diminution of technology transfer activities, an expansion is underway as an increasing number of universities shift from a relatively narrow focus on licensing intellectual property to a broader focus on facilitating translational research and investing in start-up formation from campus inventions. For example, the University of Virginia has significantly broadened the remit of its office, and restructured its capabilities, to focus on firm formation and contribution to regional economic development (Cadwalader 2103). Indeed, the Obama Administration has recently made university technology transfer a centerpiece of its economic renewal strategy but is limited by financial constraints in its implementation. The Administration encourages experienced universities to disseminate their expertise through President Obama's Webinar series. Universities also use their endowments to create venture funds and state and local governments, e.g. New York City, are committing resources to stimulate university innovation performance (Henton and Held 2013).

Columbia University has expanded the focus of its TTO from licensing to the creation of new ventures. In pursuit of this objective, universities are increasingly willing to act as angels in funding the early stages of firm-formation. New York recently realized that it lacked an MIT, as a necessary element of its hoped-for transition from a financial, real estate and corporate headquarters city to a Silicon-

Valley-like start-up center. To realize this objective quickly Mayor Bloomberg developed a competitive scheme to attract such an institution to New York, offering land, money, and a New York venue as the attractor. Cornell University, wishing to expand its presence in the city, teamed with Technion, an experienced entrepreneurial university and won the competition. Future economic growth is expected from societal investment in research and new ways are being sought to transfer technology from research institutes to the economy.[3] Traditional measures do not capture the full extent of these developments.

The analysis of university patenting and technology transfer has suffered from a misplaced focus on numbers without context, a phenomenon that Ptirim Sorokin, the founder of Harvard's Sociology Department, identified as "Quantrophrenia" in his classic work *Fads and Foibles in Modern Sociology* (Sorokin 1956). Statistics themselves, not merely unreliable data, contribute to creating misplaced objectives. This is the principle that "every measure which becomes a target becomes a bad measure" (Hoskin 1996) by inducing "a fixation on the metric rather than on the creativity and initiative that any practice requires" (Paquet 2009). Quantrophrenia is the competitive tendency inherent in statistics to become a basis of rating comparisons that may counterproductively skew activity.

More than a half-century later, a phenomenon identified as counterproductive to sociological analysis has moved beyond academia into public policy through the uncritical use of university ranking systems. For example, the former version of the U.K. Research Assessment Exercise (RAE) evaluation of universities placed great weight on publications but did not credit contribution to economic development, even though it was becoming increasingly important as an academic mission. Thus, the evaluation exercise worked against objectives set by the study's government sponsors. Making the formerly left out activity into its own indicator may solve one problem while creating another. Once patenting became a criterion of academic success in Italy, a TTO Director reported that faculty members pressured him to patent discoveries, irrespective of whether a commercial potential could be discerned.[4] Thus, a numerical criterion may drive inappropriate activity unless strong safeguards are put into place.

Moreover, not all outputs are included in the official statistics. For example, AUTM spin-off data includes what is reported by TTO's but misses those start-ups that have gone out under the radar of the TTO or were begun by undergraduates, or others, who are not employees required to disclose. Some universities keep close watch but others do not consider themselves to be "intellectual property police." The problem is not only with quality of data—"the garbage in; garbage out" phenomenon and with the reification of quantification, the misguided application of scientistic methods from the physical sciences to the social world—but also with the shortening of time frames that may cut off significant potential results that have a long gestation period. Nevertheless, tech transfer has generated an increase in revenues from $7.3 million in 1981 to $3.4 billion in 2008 (Loise and Stevens 2010:188) and from 390 patents in 1980 to 3088 by 2009 (Schacht 2012).[5]

Although most universities do not yet earn from patent licensing and technology transfer, a few have gained significantly. The Axel patents were so financially rewarding to Columbia University that it made an attempt, which ultimately failed, to change the law and extend their life. The Cohen-Boyer patent around the same time produced more than 200 million dollars in royalties for the University of California and Stanford, the home institutions of the researchers. The techniques were broadly introduced to a wide variety of firms, with the academic institutions requesting relatively modest payments from each firm (Feldman, Colaianni and Liu 2007).

Due to the early stage nature of most academic originated technology, transfer often takes place to a new firm that the university may play a key role in founding. The Cohn Boyer patents for recombinant DNA were a notable exception to this rule; the technology had obvious utility (Feldman, et al. 2005). Some firms immediately realized its potential and could be induced to license merely by making the fee reasonable; others could be convinced that the technology was relevant to their objectives. Although Niels Reimers, Stanford's Director of Technology Transfer, retrospectively viewed the license fee as a "tax," the value added by the university's TTO was the demonstration to firms that the invention was relevant to their business.

A decade or so later, Rockefeller University announced the receipt of $20 million in payment for a patent license for the "obesity gene" from Amgen, a biotechnology company, "with an agreement to pay many times that amount if the protein proves useful in treating fat people." (Kolata 1995) In this case the result did not prove useful in the end and no further funds were transferred. In the above instances, despite the pecuniary interest of the universities and the researchers in the discoveries, the traditional university industry relationship of two entities, with a gap in between, held fast. Nevertheless, despite difficulties, the gap is narrowing as institutional boundaries are broken, bridged, moved and reconfigured.

Conclusion: technology transfer and the university of the future

University technology transfer is a salient part of a broader realignment of academic mission to more fully encompass contribution to economic and social development. Especially, when considering the amounts of public funding invested in university research, it is reasonable to expect societal benefit beyond advancement of knowledge and accomplishments worthy for their own sake such as elucidation of intriguing physical phenomenon like the Higgs Boson or the reattribution of a Renaissance bronze to Michelangelo.

It is early days and a plethora of transfer innovations instituted in recent years, from Brazil's interface foundations (Plonski 2015, this volume), China's university run enterprises (UREs) (Zhou 2015, this volume) augur further innovation in transfer as, like the U.S. Bayh-Dole Act of 1980, they are globalized and reinterpreted. Stanford's Innovation system, articulated by its users if not by an official framework, distributed across and without campus, comprises immanent elements with names like StartX, MediaX, Biodesign, Spark, Ignite, D-School, ME310, Radicand, Epicenter and OTL, offer entrepreneurial mentoring, translational research funding and links to Silicon Valley networks.

These "innovations in innovation" promise to transform university technology transfer from an arm's length relationship to an element integrated into the university's teaching and research missions. The proliferation of innovation initiatives, going well beyond the TTO and the licensing of intellectual property, is an indicator of mission change. The nineteenth-century Humboldtian dual mission university is becoming a twenty-first-century Triple Helix University.

Notes

1 T. Stanco (2004) George Washington University techno-l, 180604, Start-up discussions.
2 Loet Leydesdorff, Personal Communication 22 August 2012 "University patenting after declining during the period 1999–2008 began to increase again as strongly as before. The 2011 data confirm the previously signaled trend [2010]." Chart I is credited to Professor Leydesdorff, its creator.
3 The growing literature on the drivers, dynamics and consequences of academic entrepreneurship shows the global diffusion of the entrepreneurial university model. See, for example, Barry Bozeman (2000), Technology Transfer and Public Policy: A Review of Research and Theory, *Research Policy*, 29 (4–5): 627–655; and Frank Rothaermel, Shanti D. Agung and Lin Jiang (2007) University Entrepreneurship: A Taxonomy of the Literature, *Industrial and Corporate Change*, 16 (4): 691–791.
4 Personal communication to the author.
5 These may be considered "low-ball" estimates as they are taken from results reported to AUTM, that does not include all players nor are all entrepreneurial activities on campus reported to the office. A high-end estimate may be extrapolated from studies of the entrepreneurial activities of alumni of leading universities like MIT and Stanford. See Bank of Boston (1997) The Impact of Innovation, Bank of Boston study, Boston: Federal Reserve Bank; and Charles Eesely and William Miller (2012) Stanford University's Economic Impact via Innovation and Entrepreneurship. Available online: http://engineering.stanford.edu/sites/default/files/Stanford_Innovation_Survey_Executive_Summary_Oct2012.pdf (accessed 6 May 2015).

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2 The globalization of academic innovation

Shiri M. Breznitz

Universities, acknowledged as centers of knowledge and symbols of technological frontiers, have become essential players in the generation of new knowledge and innovation. Through the commercialization of technology—the dissemination and commercialization of their ideas to the private market—universities have the ability to directly influence regional economic growth. Different commercialization models and specific universities have dominated the perception of what makes up a successful technology transfer process. These models and universities have been intensively studied, with conflicting conclusions. By extending our view from a specific commercialization model to analyze technology transfer at universities as part of a national and regional system, this edited book provides a better understanding of why certain models work better than others. Even more important is the reaffirmation that technology transfer programs need to be linked to the region and commercialization environments in which they are located.

Historically, universities were the domain of the upper classes who studied such 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. Today's university model has a public service component, offering a wider basis for research and teaching—both of which have the power to promote social change. The university service component was influenced by a neoliberal economic perspective, which holds that 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 as responsible citizens (Russell, 1993). To prove their contribution to society, many universities turned to metrics. Research commercialization happens to be one of the easier activities to measure. Most universities' annual reports these days contain many pages of data describing patents, licenses, and university spinouts even though these activities represent a very small part of the university's output and its contribution to society.

The United States was one of the first countries to seize the potential of university research. If we examine the history of the country, we find close relationships between university research and the government as well as private enterprises (Breznitz, 2014). Interestingly, the United States used university research and academic faculty early on and through both world wars. Moreover, academia has been an important source of new products and processes in fields such as aerospace and leisure, from radar to Google. As has been evident in studies of the role of government in technological development such as Mariana Mazzucato's *The Entrepreneurial State*, we find that government-funded research in the United States at universities and government labs has led to the development of some of the world leading products and processes (Mazzucato, 2013).

The Bayh-Dole Act of 1980 plays an important role in grounding the university's role in technology commercialization. The Bayh-Dole Act gave universities the rights to federally funded inventions (1981, Cornell University Law Department, 2005). As several studies point out, the impact of this legislation is questionable (Mowery, 2004; Mowery et al., 1999; Nelson R, 2001; Thursby and Thursby, 2003). Some claim that it was beneficial, and others that these changes were a natural result of relationships between university and industry as well as technological changes. Increasingly, we find more indication of complications created by the law. Authors who believe that commercialization of technology should be achieved by a professional service or that ownership should be transferred to the inventor for commercialization purposes claim that TTOs have become bureaucratic and have not been providing "enough service" or "the correct service" for industry (Kenney and Patton, 2009; Litan and Mitchell, 2010; Litan et al., 2007). Litan and Mitchell describe university technology transfer offices (TTOs) as "bottlenecks of technology." Adding market freedom to the discussion, Litan and Mitchell argue that professors should be allowed to choose the agency with which they would like to commercialize their technology. They believe that university licensing offices should strive to improve service and commercialization output or perhaps dismantle TTOs (Litan et al., 2007). Kenney and Patton (2009) support Litan and Mitchell regarding the influence of the Bayh-Dole Act on the commercialization of technology, claiming that the existing university technology commercialization model is not optimal. While the Bayh-Dole Act's purpose was to promote knowledge transfer and commercialization of technology from institutions of higher education to industry, the actual result is a bureaucratic system that delays technology diffusion through ineffective incentives and revenue-maximization goals (Kenney and Patton, 2009).

Universities around the world have attempted to adopt the "ultimate model of successful technology transfer," which many consider the model adopted in the United States. This approach, however, has both positive and negative aspects. This book focuses on both aspects. On the one hand, the U.S. model pushes universities to transfer technologies to the market. It encourages university–industry relationships and dissemination of new ideas both of universities at firms and vice versa. On the other hand, the U.S. model is not without fault (Kenney and Patton, 2009; Litan and Mitchell, 2010; Litan et al., 2007). Most universities do not possess the funding or the skills to commercialize technology, follow patents, or even to engage in proper due diligence. Moreover, by copying the U.S. or similar models, most universities ignored their own regional and environmental factors, which have consistently proven to affect university technology commercialization (Lawton Smith and Bagchi-Sen, 2012; Breznitz, 2014). Thus, in many cases, the adaptation failed and even had a negative effect on commercialization (Breznitz, 2011).

We now turn to a review of the university technology commercialization literature. In particular, we review the impact of the history and environment of the region in which universities locate, as well as the specific commercialization mechanisms established at different institutions of higher education.

Review of the literature

Existing studies show that universities' commercialization ability is affected by both external and internal factors (Lawton Smith and Ho, 2006; Mowery et al., 1999; Pike, 2002; Rahm et al., 2000; O'Shea et al., 2005). The external factors refer to the region's history and entrepreneurial environment. The history of a region in which a university operates has a direct impact on its ability to transfer technology from the public to the private domain. Did the region have an industrial base, such as Detroit? Or is it more a university town, such as Cambridge, UK? How good was the relationship between the university and industry over time? What was the regional culture? Is industry or entrepreneurship acceptable? This kind of a history and environment lead to actual policies in the form of intellectual property rights laws and tax incentives, which play an important role in the ability of universities to succeed in technology transfer and have a good university–industry relationship. In the United States, the federal Bayh-Dole Act has influenced regions in general and university–industry relationships in particular (Mowery and Sampat, 2001). The Bayh-Dole Act stipulates that the university owns the intellectual property rights for inventions that originated from a federal research grant. In Europe, each country created its own legislative incentives that formed a climate for university technology transfer. Inspired by the changes in the United States and the success of a few regions such as Silicon Valley, many European countries have attempted to implement similar policies in their regions (Lawton Smith, 2006). As we can see from the chapters about Ireland (Fitzgerald and O'Shea), Italy (Rossi, Fassio, and Geuna), Spain (García-Aracil, Castro-Martínez, Azagra-Caro, D'Este, and Fernández de Lucio), Switzerland (Gebhardt), and the UK (Lawton Smith and Glasson), they all have very different legislation with regard to university technology commercialization.

Environmental factors are also relevant to the relationship among institutions at the national and regional level. The ability of a group of local institutions to transfer knowledge and hence to affect the ability of a locality to innovate depends on their number, strength, and collaboration efforts. Sharing of information and collaboration among institutions drives innovation. According to innovation systems theory, the environment in which universities operate—the relationships between nonfirm institutions and organizations in the region, such as government, trade associations, universities, and research institutes—influences their ability to innovate (Nelson, 1993).

Moreover, universities, as part of a system of innovation, do not operate in a void; they are influenced by the networks and relationships in their specific locality (Freeman, 1995). These are symbiotic relationships, in which technology transfer influences innovation, and relationships in the system of innovation influence the ability to transfer technology. According to innovations systems theory, some regions possess a particular infrastructure that allows them to realize maximum regional learning. The learning and knowledge creation process is accomplished through a set of institutions that promote knowledge creation and learning by the local firms. Firms, institutions, and individuals share a basis of trust and understanding that differs from region to region and allows some regions to perform in a way that promotes their economic development.

As it is evident in the chapter about Switzerland, it is vital to understand that innovation results from the combined work of both public and private institutions. The public sector provides support to the private sector by enhancing production and distribution of technology and by reducing transaction costs (Lundvall et al., 2002). Consequently, universities and research institutes play an important part in the national and regional innovation process. This point can be effectively analyzed using Etzkowitz's (1995) "Triple Helix" model, which, with its focus on the communication networks among university, industry, and government, provides an argument for commercializing scientific knowledge. Etzkowitz and Leydesdorff (2000) argue that universities, industries, and governments increasingly find themselves working together, understanding that economic development can be achieved by creating and fostering innovative environments.

Developing an innovative environment at a national or regional level can be achieved through the incorporation of university spinouts, specific policies, networking among firms and government laboratories, and basic research conducted at universities. With globalization, corporations have increasingly discovered the advantages of tapping into the best research and practices in many places around the world. In other words, knowledge and top-quality research have geographical characteristics (Etzkowitz and Leydesdorff, 2000). As such, they are concentrated in specific locations and are based on regional learning, networking, and technology transfer. Not all countries or regions possess the best knowledge, and while globalization allows them to import and export this knowledge, corporations still need to tap into the particular endowments of specific localities.

Internal factors, such as university technology transfer culture, policy, and organization have been shown in previous studies to have an impact on the ability of universities to commercialize technology (Shane, 2004; Roberts, 1991; Zucker et al., 1998; Clark, 1998; Lockett and Wright, 2005; Kenney and Goe, 2004). The first is the university's entrepreneurial culture, which is formed to support risk-taking, innovation, new business creation, and a willingness to collaborate with industry (Bercovitz and Feldman, 2007; Clark, 1998; James, 2005; Kenney and Goe, 2004; Schoenberger, 1997). Studies that focus both on organizational change and university culture emphasize the organization and individual view toward commercialization and entrepreneurship as the basis of university technology transfer success (Bercovitz et al., 2001; Clark, 1998; Kenney and Goe, 2004).

Creating an entrepreneurial culture affects the university and its researchers in multiple ways: it allows faculty to work on applied research and to accept the ability of academic research to make profit and a public impact, as well as creating opportunities for founding new companies based on university research.

The second internal factor is technology transfer policy, which affects the university's ability to patent, license, and spin out companies (Lawton Smith, 2006; Link and Siegel, 2005; Shane, 2002; Siegal and Phan, 2005; Thursby and Thursby, 2005; Zucker et al., 2002). Studies find that policy plays an integral part in universities' success in technology transfer, particularly in commercialization of university-developed technology. One such policy is intellectual property rights (IPR), which at universities refers to copyrighting academic publications—that is, journals and books—and patents filed by the university for an invention that was the result of university research. The chapters on Canada (Hepburn and Wolfe) and Italy (Fassio, Geuna, and Rossi) indicate to what extent IPR regulations differ from one country to another. According to these studies, in Italy, faculty and staff own their IPR, while Canada has a mixed-used policy in which each institution has its rules with regard to ownership of intellectual property (IP). But individual ownership of IP can be problematic. In Italy, while individual researchers own the IPR of their inventions, most universities lack the managerial experience and the commercial orientation to assist them with the commercialization process.

Incentives are an important policy that has been showed to impact commercialization. According to Di Gregorio and Shane (2003) and Link and Siegel (2005), changes in faculty incentives change their behavior. If a higher share of royalties is allocated to the inventor (the faculty member), universities will license more inventions to existing companies. Furthermore, Shane (2004) claims that when a lower share of royalties is distributed to inventors more spinouts will result. Since the royalty share is low, the only way for inventors to increase their return on an invention is by founding a company and becoming a major shareholder. Another aspect of technology transfer policy that influences a university's spinout capability is the extent to which research collaboration is permitted. Faculty collaboration with industry through consulting or research projects affects industry-sponsored research as well as the university's culture and view of applied research. University–industry research collaboration promotes financial support from industry, which supports students or provides grants for particular research. Moreover, if the research results in an invention, industry will purchase the invention equity or license the technology from the university (Blumenthal et al., 1996; Thursby and Thursby, 2005; Zucker et al., 2002). Shane adds that the proportion of industry's contribution to research funding is a predictor of the level of university spinouts. Spinout formation grows with the proportion of industry funding (Shane, 2004).

The third internal factor is the TTO. Depending on its policy, staff, mission statement, and even its "position" within the organization, the university's TTO has the ability to influence technology commercialization (Bercovitz et al., 2001; Clarysse B. et al., 2005; Link and Siegel, 2005; O'Shea et al., 2005; Owen-Smith and Powell, 2004; Siegel et al., 2004). TTOs at universities have four main purposes: (1) to evaluate inventions and determine whether they are patentable; (2) to patent the inventions; (3) to license the technology; and (4) in some cases, to assist in the creation of spinout companies. A TTO's responsibilities are flexible and open to interpretation, however, and they differ significantly between universities. Some universities will patent only a technology for which there is market demand. For many, the spinout of companies is not a priority; their goal is to secure income from licensing their patents. Increasingly, most universities, regardless of their research capabilities, have established a TTO (Feldman and Breznitz, 2009; Sampat, 2006), and they have become an indicator of university commercialization and entrepreneurship. Vietnam, where universities still harbor a negative view of the establishment of TTOs, is a good example of a lack of engagement in commercialization.

The level of resources associated with the TTO affects its commercialization ability. Several studies show that TTOs that have personnel with higher levels of education and business experience tend to have a better understanding of the technology and negotiation processes at firms (Lockett and Wright, 2005; Shane, 2004; O'Shea et al., 2005). Since university and industry have different perspectives, highly educated TTO employees who have knowledge of both the technical and business jargon reassure both inventors and investors that their product is getting the best available treatment. Other factors that relate to the availability of resources are the use of outside lawyers and the compensation of technology transfer officers (Siegel et al., 2003; O'Shea et al., 2005; Owen-Smith and Powell, 2001; Shane, 2004). A study by O'Shea et al. (2005) found that the historical background and past technology transfer success of each university is related to future capabilities and options for the university with regard to spinout capability. When a TTO successfully had an invention go through the commercialization process and receives returns in the form of royalties, the office is strengthened and motivated to continue with the commercialization process. Yale University, for example, has had success in technology commercialization via its patenting of Zerit™, one of the drugs used in the treatment of HIV/AIDS.

Organization of this book

The literature reviewed above indicates how both external and internal factors affect the ability of a university to commercialize technology. In the individual chapters of this book, we explore this process in twelve countries, using a country-centric approach as well as analysis of specific universities.

Following the two introductory chapters in Part I, where Chapter 1, by Henry Etzkowitz, describes the evolution of university technology transfer, we offer four chapters in Part II on the less discussed faults of the U.S. model. In Chapter 3, Maryann Feldman and Paige Clayton follow the increasing litigation in which universities are involved, indicating how early such litigation started. Many of the TTOs are dealing with legal filings and defending themselves from litigation rather than commercializing university technology. Chapter 4, by Henry

Etzkowitz, examines how the perception of a successful TTO like the one at Stanford University changed from enabling some of the most disruptive technology to becoming a gatekeeper that is holding technology back in exchange for financial gains. Chapter 5, by Henry Etzkowitz and Devrim Göktepe-Hultén, demonstrates that best practices used in some of the most successful TTOs do not fit all universities. Moreover, using the conventional metrics of patents and licenses, while not taking into consideration regional and historical factors, leads to misrepresentation of less established TTOs. Chapter 6, by Ashley J. Stevens, Jonathan J. Jensen, Katrine Wyller, Patrick C. Kilgore, Eric London, Sabarni K. Chatterjee, and Mark L. Rohrbaugh, documents the shift in roles between the public and the private sector in the U.S., where the public sector now plays a more direct role in the applied research part of drug discovery.

In Part III, we turn to a global perspective on technology commercialization, dividing our discussion between developed and developing counties according to the level of university commercialization capability. These case studies examine policies and culture of university involvement in economic development, relationships between university and industry, and the commercialization of technology first developed at universities. In addition, each chapter provides examples from specific universities in each country from a regional, national, and international comparative perspective.

The terms "developed" and "developing" as used here distinguish between countries that adopted a more U.S.-centric commercialization model and those that have not. The "developed" ones include those in which there is a focus on university technology commercialization, whether through a collaboration, state involvement, or industry leadership. "Developing" countries, addressed in Part IV, are those in which there is still no particular policy toward university technology commercialization or the policy is in place, but the current conditions do not allow for progressive commercialization or university–industry collaboration.

The "developed" countries include Switzerland, the UK, Ireland, and Canada. These countries are very different in their approach to the commercialization of university research but are highly focused and driven by technology spinning out of universities. Chapter 7, on Switzerland, by Christiane Gebhardt, describes the strong push by the federal government and collaboration between industry and academia. Chapter 8, on the UK, written by Helen Lawton Smith and John Glasson, demonstrates eloquently how regional differences affect universities' ability to commercialize technology. Although the British government implemented many different policies to support university commercialization of technology, the regional impact was the result of the different universities' abilities to commercialize technology as well as the demand side from the region itself. The four universities described in this chapter are leaders with regard to technology transfer. However, they vary widely in the extent of their success with commercialization. The chapter shows how important regional history and environment are to the success or failure of technology transfer models. Chapter 9, on Ireland, by Ciara Fitzgerald and Rory P. O'Shea, demonstrates the systematic push by the Irish government starting in the 1980s to build up research and technology transfer infrastructure. Irish universities chose to adapt to the commercialization push, though, as the authors claim, they still face many roadblocks in employing transparent policies regarding the share of royalties, leave of absence, length of IP negotiation, and equity investment policy. Chapter 10, on Canada, by Nicola Hepburn and David A. Wolfe, provides excellent evidence of the power that specific institutional characteristics have on technology commercialization. Unlike in the United States, Canadian universities each establish their own intellectual property regimes, as seen in the universities studied in this chapter. Even though the universities discussed are all active in technology commercialization, they use different models and policies to achieve their goals, which developed out of their different histories.

Then, in Part IV, we consider "developing" countries, where we find some efforts to develop technology commercialization. However, either these countries have not been able to embrace this push toward university research or their academic system is not well equipped to allow for commercialization and a relationship between universities and industry. Chapter 11, on Spain, by Adela García-Aracil, Elena Castro-Martínez, Joaquín M. Azagra-Caro, Pablo D'Este, and Ignacio Fernández de Lucio, indicates that in the early 1990s the country gradually changed its policy toward university commercialization. Spanish universities have become more research oriented and have experienced a substantial increase in their knowledge and technology transfer activities. However, the social and economic impact of university–industry relations remains at a nascent stage. Chapter 12, on Thailand, by Jarunee Wonglimpiyarat, describes a country in the early stages of adopting a government policy toward university technology commercialization. The government realizes the importance of research as a basis for national innovative capability and thus launched urgent policies to support universities by endorsing national research universities in 2009. However, as indicated by the author, very few patents have been issued to the universities and even a smaller number have been commercialized by industry. The status of university technology transfer in Russia is the subject of Chapter 13, by Tatiana Pospelova. In Russia historically, applied research was conducted not at universities but mostly in government research labs. Only since 2009 has there been a government push toward an innovative economy that relies on academic research. The most obvious manifestation of this is the latest Russian legislation, which has given Russian universities the rights to all inventions funded by the state. However, in reality, the law is not enforced and when faculty believe that they have a worthy invention, they often form their own company outside the university. The author shows that the historical legacy at universities with regard to conducting basic research creates barriers for technology transfer and university–industry relationships. Chapter 14 on Italy, by Federica Rossi, Claudio Fassio, and Aldo Geuna, is very similar to Chapter 10 on Spain. Italian universities have a long tradition of interaction with industry, especially in applied fields such as engineering and chemistry. However, they began to formally acknowledge the importance of