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How Universities Promote Economic Growth

Editors
Shahid Yusuf and Kaoru Nabeshima

THE WORLD BANK

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Foreword

The American University of Paris (AUP) is very pleased to have cohosted the symposium on University-Industry Linkages and Development on March 27, 2006, in cooperation with the World Bank Institute and the Social Science Research Council, sponsored by the World Bank Development Economics Department. The general aim and interest of AUP, in particular its new Graduate School of Government, is to be at the heart of academic and policy debates on issues of the day, such as the multiple links between universities and the private sector, as well as their many implications for global welfare.

AUP was founded in 1962, making it the oldest American institution of higher learning in Europe. An independent college of fine and liberal arts and sciences, AUP is developing into a small but top-notch, fully fledged university with graduate programs and new research initiatives. Characterized as an urban institution located in downtown Paris and teaching students of about 100 nationalities, AUP has been successfully developing diverse partnerships with private sector institutions, foundations, international organizations, and governments at all levels. These partnerships have been aimed at gaining academic excellence, creating knowledge, and benefiting the various AUP constituents.

Here at AUP, we are honored to have cohosted this symposium. The mission of the American University of Paris is to educate generations of academic, social, political, and intellectual citizens of the world and to enhance the advancement of scholarship in the arts and sciences in an international, multicultural, and plural environment. The symposium will undoubtedly contribute to strengthening AUP research capacities by fostering scholarly collaboration and interaction, and we believe it will significantly help address issues critical for modern societies and of deep concern to the academic community.

Finally, the symposium is of utmost importance for the AUP Graduate School of Government, because our forthcoming Master of Arts in Strategic Public Policy Program will include a concentration in "The Knowledge Industry, Innovation Policies and Development." In this regard, this volume is expected to provide invaluable resources and inputs for future courses that will be part of the curriculum and further research activities undertaken by AUP faculty and potential visiting scholars.

We thank all participants for their significant contribution to this workshop and are confident that its most visible fruit, this publication, will yield benefits to our societies.

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Preface

This volume is part of a series of publications emerging from a study cosponsored by the government of Japan and the World Bank to examine the future sources of economic growth in East Asia. The study was initiated in 1999 with the objective of identifying the most promising path to development in light of emerging global and regional changes.

Earlier volumes have examined aspects of the innovation system in East Asia, issues pertaining to the competitiveness of firms, and factors influencing the economic performance of countries in the region. The purpose of this volume is to examine the role of universities in enhancing technological capability in Asian as well as other industrial countries and to discuss the policy measures being applied to that end by governments, corporations, and universities.

The financial backing of the government of Japan, through its Policy and Human Resources Development Fund, has provided vital support for this project, as have senior public officials who gave generously of their time. We are deeply grateful to Haruhiko Kuroda, Takashi Kihara, Naoko Ishii, Masahiro Kawai, Kiyoshi Kodera, Rintaro Tamaki, Junichi Maruyama, and Takatoshi Ito. The symposium on which this book is based was cosponsored by the American University of Paris (AUP), the Social Science Research Council, and the World Bank Institute. We thank

Martin Grandes, Eric Hershberg, and Jean-Eric Aubert for the time and effort they put into helping organize the symposium and into making it a success. We owe special thanks to the AUP for providing us with an elegant conference venue in the heart of Paris and to Laetitia Gonsette and Michelle Lemaire for the enormous help they provided with the logistics.

At the World Bank, the Development Research Group has provided a home for the study. We are especially indebted to Alan Winters for his encouragement and staunch support.

The study team was ably supported by the research and organizational skills of Jimena Luna, Jue Sun, and Tristan Suratos. We are grateful to them.

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Acronyms and Abbreviations

AII	Industrial Innovation Agency (Agence de l'Innovation Industrielle) (France)
AIT	Asian Institute of Technology
ANR	National Research Agency (Agence Nationale de la Recherche) (France)
AT	anchor tenant
AUP	American University of Paris
BCIP	Biotechnology Clusters Innovation Program (Ontario)
CBR	Centre for Business Research
CEA	Atomic Energy Commission (Commissariat à l'Energie Atomique) (France)
CIC	center of industrial collaboration
CIIE	Centre for Innovation, Incubation, and Entrepreneurship
CNES	National Space Study Center (Centre National d'Études Spatiales) (France)
CNRS	National Scientific Research Center (Centre National de la Recherche Scientifique) (France)
CRL	central research laboratory
CSIR	Council for Scientific and Industrial Research (India)
CTI	Commission for Technology and Innovation (Switzerland)

DTI	Department of Trade and Industry (United Kingdom)
EPF	Institute of Technology (École Polytechnique Fédérale) (Switzerland)
EI	Engineering Index
ETAN	European Technology Assessment Network
EU	European Union
FITT	Foundation for Innovation and Technology Transfer
G7	Group of Seven (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States)
GDP	gross domestic product
GE	genetic engineering
GUIRR	Government-University-Industry Research Roundtable
HDD	hard disk drive
HEIF	Higher Education Innovation Fund (United Kingdom)
HEROBC	Higher Education Reach-Out to Business and the Community (Scheme) (United Kingdom)
IC	integrated circuit
IDEMA	International Disk Drive Equipment and Materials Association
IIMA	Indian Institute of Management, Ahmedabad
IISc	Indian Institute of Science
IIT	Indian Institutes of Technology
IL&FS	Infrastructure Leasing and Financial Services
IMR	Institute for Materials Research
INSERM	National Institute for Health and Medical Research (Institut National de la Santé et de la Recherche Médicale) (France)
IP	intellectual property
IPC	Industrial Performance Center
IPRs	intellectual property rights
ISTP	Index to Scientific and Technical Proceedings
IT	information technology
ITRI	Industrial Technology Research Institute
KOF	Institute for Business Cycle Research (Konjunkturforschungsstelle) (Switzerland)
KRP	KR Precision
KTH	Royal Institute of Technology (Kungliga Tekniska Högskolan) (Sweden)
MERIT	Maastricht Economic and Social Research and Training Centre on Innovation and Technology

MIT	Massachusetts Institute of Technology
MITI	Ministry of International Trade and Industry (Japan)
MNC	multinational corporation
MOE	Ministry of Education (China)
MOST	Ministry of Science and Technology (China)
NCL	National Chemical Laboratory (India)
NIE	newly industrializing economy
NOC	NUS Overseas College (Program) (Singapore)
NSC	National Science Council (Taiwan, China)
NSTDA	National Science and Technology Development Agency (Thailand)
NUS	National University of Singapore
OCRI	Ottawa Centre for Research and Innovation
OECD	Organisation for Economic Co-operation and Development
OFS	Federal Office of Statistics (Office Fédéral de la Statistique) (Switzerland)
PARC	Palo Alto Research Center
PE	protein engineering
PRI	public research institute
R&D	research and development
RDA	regional development agency
RIEC	Research Institute of Electrical Communication
S&T	science and technology
SBIR	Small Business Innovation Research (Program) (United States)
SBRI	Small Business Research Initiative (United Kingdom)
SCIE	Science Citation Index Expanded
SEC	Science Enterprise Challenge (United Kingdom)
SET	science, engineering, and technology
SIDBI	Small Industries Development Bank of India
SIIC	SIDBI Innovation and Incubation Centre
SINE	Society for Innovation and Entrepreneurship (India)
SJTU	Shanghai Jiao Tong University
SMART	Small Firms Merit Award for Research and Technology (Program) (United Kingdom)
SMEs	small and medium enterprises
STA	Science and Technology Agency (Japan)
TeNeT	Telecommunications and Computer Networking (Group)
TLO	technology licensing office

TOP	The Ottawa Partnership
TRIMS	Trade-Related Investment Measures (Agreement)
TRIPS	Trade-Related Aspects of Intellectual Property Rights (Agreement)
TRRA	Toronto Region Research Alliance
TSB	Technology Strategy Board (United Kingdom)
TSMC	Taiwan Semiconductor Manufacturing Corporation
TTCAP	Toyota Technical Center–Asia-Pacific
TTI	technological top institute
TTO	technology-transfer organization
UAS	university of applied science
UC	University of California
UED	Urban Economic Development (Branch) (Ontario)
UIL	university-industry link
UMC	United Microelectronics Corporation
UNIEI	University of Nottingham Institute for Enterprise and Innovation
USPTO	U.S. Patent and Trademark Office
VLSI	very-large-scale integration
WTO	World Trade Organization

CHAPTER 1

University-Industry Links

Policy Dimensions

Shahid Yusuf

The evolving links between the university and the business sector are becoming a major focus of policy as the role of technology in development expands. This opening chapter offers a perspective on those links, examines some of their characteristics in middle- and high-income countries, and describes policies that seek to multiply links and enhance their fruitfulness. At this stage, whether those policies are the right ones and whether the dynamic they are introducing will persist and lead to improved outcomes is difficult to gauge. But clearly, change is in the air, and it is useful to frame the observations in the balance of this chapter within a brief discussion of why universities are becoming more closely associated with technological change.[1]

The modern university, with its mix of teaching and research functions, was the brainchild of the Prussian educational philosopher Wilhelm von

[1] In this vein, Etzkowitz and Leydesdorff (2000, 112) note, " In one form or another, most countries and regions are trying to realize an innovative environment consisting of university spin-off firms, trilateral initiatives for knowledge-based economic development, and strategic alliances among firms, government laboratories, and academic research groups."

Humboldt. In 1810, he became the founding father of the University of Berlin, which put into practice his ideas and became a model for other universities in Europe and the United States. For almost 600 years, universities had served as little more than training grounds for lawyers, clerics, and other professionals. Humboldt changed all that by making research a vital complement of teaching, by emphasizing science, by urging traffic across disciplinary boundaries, and by attempting to make the university contribute more directly to economy and society (Ruegg 2004). Humboldt changed the terms of the discourse, and universities have been adapting and assimilating the model he espoused ever since. The university's role in imparting higher education is straightforward and consistently reiterated. The two additional roles it acquired post-Humboldt—that of conducting basic research to advance knowledge and that of contributing to the development and assimilation of technology for civilian or military uses—have been adopted partially and unevenly over time and among countries by a few elite universities.[2] Generally, basic research has appeared to be a more logical extension of teaching activities and one favored by the academic mindset. Applied science for the purpose of devising commercial technologies has had a more uneven passage. It has been decried as a digression, possibly a distraction, and arguably inimical to the central role of the university, which is to teach. Nevertheless, it has also enjoyed support, and as Etzkowitz and Leydesdorff (2000, 115) have observed, "the practical impetus to scientific discovery is long-standing."

The pursuit of science has often opened doors to technology with commercial applications. Many scientific results have helped spark innovations of industrial or agricultural value. Others have served to enlarge the stock of usable knowledge and to improve techniques in many different fields. These knowledge spillovers from institutions of learning have a lengthening history. In the more distant past, most of the spillovers were mediated by those who trained at the universities and then took up business pursuits, other professions, or farming. Until the late 19th century, very little research was conducted at Oxbridge universities, for example. Most technological advances—for instance, in railways—were the result of applied research done by firms. But closer to the present, as industrialization gathered momentum, more universities became directly involved, formally and informally, in the development of technology for commer-

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[2] See Etzkowitz and others (2000) on the evolution of university autonomy; attitudes toward research and relations with industry in Japan, the United States, Europe, and Latin America on government policies; and the dilemma facing researchers in Latin America. See also Sutz (1997).

cial purposes. German universities were a valuable source of scientific knowledge and expertise for the nascent chemical and pharmaceutical industries from the late 19th century onward (Mowery and Rosenberg 1998). They, in turn, stimulated research in universities and corporations in the United States through the circulation of students trained at German universities (MacGarvie and Furman 2005). Biomedical and biological research began to flourish at the University of Pennsylvania, the University of Delaware, and Rutgers, for example, thus inducing the simultaneous growth and colocation of corporate research labs of companies such as Sterling, Merck, DuPont, and Eli Lilly. These companies, in turn, encouraged through financial and other channels a further expansion of training and research in universities (MacGarvie and Furman 2005). The engineering faculty of specialized institutions such as the Massachusetts Institute of Technology (MIT) was an important resource for industry in Massachusetts. Starting in the 1930s, MIT was active in broadening the training of engineers to include a solid grounding in the engineering-related sciences (Tadmor 2006). As noted by Foray in chapter 3, the discipline of engineering has become a valuable bridge from the university to business.[3] One of the specific objectives of the American land grant colleges, which were created by the Morrill Land Grant Acts in 1862 and 1890 and by the Hatch Act of 1887, was to assist rural communities in improving farming practices.[4] Japan, which borrowed heavily from the German university system, used the imperial universities it began establishing at the end of the 19th century—starting with Tokyo University in 1877 and Kyoto University in 1897—as vehicles for absorbing Western scientific knowledge and harnessing it for the purpose of accelerating modernization.

What emerged and persisted through almost the first half of the 20th century was a state of affairs wherein small numbers of universities in the industrial countries engaged in research and technology development with the business community to varying degrees and through formal as well as informal channels. The majority of tertiary-level institutions devoted themselves to teaching and depended on their graduates to diffuse knowledge. Most universities did not formally engage in research as research is now known.

[3] Initiatives by Vannevar Bush at MIT and Frederick Cottrell at Berkeley during the post-World War II era promoted applied research and the links with industry (Etzkowitz and others 2000; Lim 1999).

[4] The Morrill acts provided each college with 90,000 acres of land, and the Hatch Act funded research stations for agricultural research (MacGarvie and Furman 2005).

World War II was a boon for technology development. The jet engine, nuclear power, radar, computers, rocket propulsion, and many other technologies took root in the 1940s, and in most instances universities had a hand in development (Hambling 2005). Before the war, university research—where it was conducted—had the dimensions of a cottage industry. The programs launched during the war and the scale of the funding provided by the government, mainly in the United States, made large-scale scientific research an integrated part of the activities of several leading American universities. Later, when the Cold War gathered momentum, research for the purpose of technology development became more firmly entrenched. Massive state support for research became institutionalized in the United States, along with equally massive spending on research and development (R&D) by the corporate sector. A portion of this money was funneled to the universities and helped formalize and cement university-industry links that had begun multiplying in the 1940s. As industrial countries such as France and Japan attempted to catch up with the United States, they, too, launched major state-financed R&D programs, although such programs were mainly aimed at the corporate sector and government-owned laboratories (see Jiang, Harayama, and Abe in chapters 8 and Duby in chapter 16).[5] Although the leading European and Japanese universities, as well as universities in the Soviet bloc, conducted some basic research and technology development, the scale was limited, and formal relations with businesses to develop or transfer technologies were less common than in the United States. Such relationships did begin to flower in Japan, however, as a result of initiatives by the government (for example, special funds for graduate schools and joint research with industry) and by universities such as Tohoku (Yamamoto 1997).

Innovation Matters More

Two developments have raised the salience of innovation. In the realm of economic theory and empirical research, models of endogenous growth have underscored the central contribution of knowledge accumulation to gross domestic product growth (Lucas 1989; Romer 1989). The day-to-day experience of firms convincingly buttresses these models. Market

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[5] In Japan, the Ministry of International Trade and Industry helped stimulate the private sector's development of semiconductors by launching a project on large-scale integrated circuits (Kimura 1997).

competition is becoming more closely keyed to innovation. For many consumer and electronic products, the life cycle from introduction to maturity, obsolescence, and withdrawal is becoming far shorter (Agarwal and Gort 2001). Many electronic products are superseded by new models within months. This quick obsolescence is true also for products in other categories, albeit to a lesser degree. For that reason, ceaseless innovation that permits companies to continuously refresh their product lines is becoming a necessity for many. Even when product innovation is not the central concern, as in the engineering and transport industries, for example, companies still have to engage in process innovation to pare costs, raise quality, and reduce defect rates, all in the interest of sustaining competitiveness. Globalization has intensified the pressures. As distances and market barriers shrink, the number of actual and potential competitors has increased manifold. With so many low-wage countries now entering the market and with codified industrial technologies facilitating entry, innovation is frequently the only survival strategy for firms in middle- and higher-income countries (Berger 2005).

Although the increased need for innovation has created strong incentives for investment in R&D by the business sector and investment expenditures have climbed steadily, at least in absolute terms, firms are coming to terms with three concerns. First, as the technological frontier is pushed outward, the cost and complexity of technologies goes on mounting, and many new technologies are materializing at the intersection of several disciplines or subdisciplines (Foray, chapter 3). As a consequence, costs are rising, and even the largest firms are finding the independent pursuit of research projects much harder. This factor is encouraging firms to adopt "open" innovation systems that favor partnerships, alliances, consortia, and coordination of research effort (Chesbrough 2003; Hall and Mairesse 2006).[6]

Second, because technology remains tethered to basic science, at a certain point further advance becomes impossible without a deepening of scientific knowledge in specific areas or scientific breakthroughs that loosen or eliminate particular constraints. In the past, many of those scientific advances were made by individual investors working independently in their garages, in universities, or in companies (Schwartz 2004). Starting with the German pharmaceutical and chemical companies in the

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[6] Knowledge exchange between partners in an alliance occurs more easily and efficiently than in firms not yoked together by such arrangements (Gomes-Casseres, Jaffe, and Hagedoorn 2006).

late 19th century and the early decades of the 20th century, large firms began pursuing basic research alongside the development of technology in corporate labs. General Electric established the first corporate laboratory in the United States in 1900.[7] The number of such laboratories rose to four in the 1890s and passed a thousand by the 1930s (Etzkowitz 2002). Independent inventors are still able to come up with remarkable discoveries, and large research-oriented firms have not withdrawn from the vineyards of basic science. Since the 1990s, both the scale of their effort and their output have diminished, however. Even the largest corporations are being forced by market and shareholder pressures to control costs far more rigorously, and cutting back on curiosity-oriented basic research with unpredictable commercial prospects has become expedient.[8] Furthermore, the conduct of cutting-edge research now often requires teamwork—sometimes straddling several disciplines—and expensive equipment for conducting experiments and measuring results (Galison and Hevly 1992). Those needs require deep pockets and a breadth of expertise that rules out the lone inventor and forces even corporate giants to trim their research sails. The downsizing of Bell Laboratories and of Xerox's funding for the Palo Alto Research Center (PARC)[9] in California reflects these new realities.

Third, the ending of the Cold War and, with it, the intensity of the arms race has affected the scale, the mix, and the distribution of research funding in physical sciences from governments in leading industrial nations. Defense contractors no longer receive the volume of support they once did for the development of technologies with a direct or distant relation to new weapons systems[10] (see chapter 14 by Garnsey). Government research labs, many of which concentrated almost exclusively on defense projects and often engaged in basic research as well as in technology development, have also seen their funding beginning to dry up.[11] Although other threats, real or imagined, help sustain defense or security-related research, the level has undoubtedly fallen compared

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[7] It was housed in a barn close to the Erie Canal in Schenectady, New York. Willies Whitney, an MIT chemist, was the first director.

[8] U.S. corporations spent US$40 billion on applied and basic research in 1998. More than $100 billion was devoted to development (Business-Higher Education Forum 2001).

[9] PARC now also relies on partnerships with Fujitsu and the Scripps Research Institute.

[10] Such research contributed to the information technology revolution and creation of the Internet.

[11] For example, French authorities have embarked on policies to encourage entrepreneurship by researchers in state laboratories, private venture capital, and new start-ups. These policies could stimulate the commercialization of technologies (Trumbull 2004).

with the heyday of the Cold War. More of the public money for research in member countries of the Organisation for Economic Co-operation and Development (OECD) now goes into health-related fields and the social sciences.

A fourth contributing factor is that the university sector, which had expanded significantly in the industrial countries, faces the prospect of declining enrollments because of demographic changes in most of the OECD countries and must either find new ways of augmenting earnings or shrink in size. Expanding basic research with the support of public funds and entering into arrangements with the business sector to develop technologies offer universities with the capacity to conduct research an avenue for maintaining the scale of their operations.

Making Policies for University-Industry Links

Those reasons, in conjunction with the comparative advantage of certain universities to complement teaching with research, are behind the gathering interest in university-industry links (UILs) as a vehicle for supporting, if not accelerating, technology development. Strikingly, virtually every industrial country is moving to make university-industry links a centerpiece of its innovation systems, and the notion of a triple helix—representing the symbiotic relations yoking together the government, the universities, and the business community—has acquired wide currency (Etzkowitz 2002; Etzkowitz and Leydesdorff 2000).[12] Even more striking is the speed with which industrializing countries (such as China and India, which are constructing innovation systems) have embraced technology as the key to development and, with it the utility of research-oriented universities as a means of augmenting the innovation capability of the economy (Sigurdson 2005). The emergence of this so-called consensual view of the role that universities are now expected to play is at odds with the nature of the achievement of even the most entrepreneurial universities in the United States. As chapters 4, 10, and 14 by Hughes, Mowery, and Garnsey, respectively, spell out, universities contribute relatively little to patenting, licensing, and spinoffs, except in the life sciences. Most firms still attach more importance to informal contacts with universities that relate to the recruitment of graduates, internships, and consulting. And in the United States, firms are having

[12] See also the paper in Etzkowitz and Leydesdorff (1997).

difficulty with the aggressive behavior of some universities regarding the sharing of property rights and licensing.

University-industry links as an idea and even UILs as a major strand of innovation strategy could remain far removed from universities as drivers of growth unless a number of major policy steps are proposed and implemented. Only some of them are policies of the central government. In a world where globalization and localization are occurring in tandem, three other players share almost equal responsibility for making policies and carrying them through. They are the universities themselves, subnational governments, and business firms. A national innovation system in which all these policies could effectively be calibrated and coordinated would be ideal, but inevitably it is difficult to implement. In many instances, universities are not ready to take on additional roles. The objectives and expectations of individual participants differ and diverge, and tried and tested policy tools are few. Most alarmingly, the globalization of research spurred by multinational corporations (MNCs) and the use of information technology (IT) encourage firms to look beyond their national boundaries (Carlsson 2006). Just as researchers are much readier to collaborate with colleagues from other institutions throughout the world, companies are seeking expertise in technology much more widely, forcing even universities in the Netherlands and Switzerland with a track record in the development of technology to worry about their competitiveness in this new and "flatter" world (see Soete and Foray in chapters 2 and 3, respectively; Carlsson 2006; Friedman 2006; Kim, Morse, and Zingales 2006). Still, for the moment, there is no turning back. A broad coalition of forces is determined to make the universities contribute more directly to technological advances, and a variety of policies are being introduced. If innovation truly is decisive for the competitiveness of firms, it would not be an exaggeration to say that much hangs on the outcome of these policies. If universities can significantly augment the flow of innovation through their own basic and applied research across a number of disciplines, and not just the life sciences, and if such innovations can be used by the business sector, countries with dynamic university sectors can count on higher rates of growth, especially if the benefits of new findings tend to remain localized for a period of time.

Although policies relating to university-industry links are not easily compartmentalized, a degree of decomposition is both possible and useful to highlight the responsibilities of the individual entities. This volume divides the policies into four groups and comments on the salient issues, as well as describes initiatives being taken across the world. Experience with these initiatives can be a valuable source of guidance for industrial and industrializing countries alike, because universities are being viewed as central to nurturing of technology in all countries that are serious about strengthening their national innovation systems.

National Policies

Ultimately, most of the technological advances that have economic consequences can be traced indirectly or directly to universities, either through the training provided, the knowledge spillovers, or the actual research conducted or through UILs that enabled firms and faculty members to collaborate in the development of technologies. Even in Japan and the United States, however, the output of technologies from universities as measured by patents is relatively small, although universities account for the majority of papers (many coauthored with researchers in firms) published in refereed scientific journals. The case is the same in European countries, and to some it suggests the potential for more technology development by universities. Others claim that the division of labor, whereby universities educate students and university-based researchers add to the storehouse of knowledge through their publications, is a good one. It keeps the focus on teaching, and basic research largely complements the teaching and lends excitement as well as energy. According to this philosophy practiced (albeit with diminishing commitment) by leading universities such as Johns Hopkins, by being drawn into the crafting of commercializable technologies and into links with the business sector, the university is likely to see its primary role diluted, and the quality of education could suffer (Feldman and Desrochers 2004). Those arguing on such lines can also point to the great advances in technology during recent decades that suggest no fundamental change in the role of universities is called for. The system is not broken, they argue.

But the consensual view that times have changed, for the reasons cited earlier in the chapter, is gaining ground. With the United States and a few European countries in the lead, national governments have begun applying with greater force a number of policies to promote research in universities and to encourage UILs. In East Asia, the governments of Japan, China, and Singapore are also broadening and intensifying their efforts as described by Jiang, Harayama, and Abe (chapter 8); Wu (chapter 11); and Wong (chapter 12).

National governments initially set the stage for the emergence of university-industry links through their higher education and innovation strategies. Those strategies determine how much is spent on tertiary education; how it is distributed across institutions; what kinds of disciplines are emphasized; what student quotas exist, if any; how much autonomy teaching institutions enjoy; what financing arrangements they have; and what kind of competition exists among them. Each strategy has a bearing on the likelihood and nature of UILs. In particular, the heterogeneity among tertiary institutions, the competition among them, and their autonomy with respect to policies and benefits are crucial, and such elements explain the success of universities in the United States (see chapter 10 by Mowery; "Brains Business" 2005). Governments are now becoming more ambitious in their quest for results.

One set of policies aims to augment the supply of university- and research institute–based research by providing direct grants—earmarked, matching, or block—for selected activities, for creating and provisioning lab facilities, and for incubators.[13] In 1998, the U.S. federal government provided $13.5 billion in research financing to universities; corporations contributed $2 billion (9 percent). Tax incentives for private foundations and businesses for such purposes help supplement state funding. Providing scholarships for students enrolling in science and technology (S&T) fields and, where possible, setting enrollment quotas for individual disciplines can reinforce these measures.[14] The incentives extend to foreign students and can be backed, as in the United States, by immigration rules favoring individuals with skills and experience that are scarce domestically.

The push toward research and its commercialization in the United States, in Europe, in Japan, and now in China has acquired greater force, because governments are trimming their contributions to university budgets and requiring them to supplement their earnings from the fruits of their research, whether through knowledge transfer, spinoffs, or equity stakes in start-ups. By supporting competition between public and private universities, the state has also ratcheted up the pressure on once-protected state universities, as in Japan and Singapore, to bid for students and faculty on the basis of their reputations not only as teaching institu-

[13] The bulk of the government-financed research in France is by state-owned research centers, many affiliated with universities. In Taiwan, China, the government-owned Industrial Technology Research Institute is a pillar of the island's knowledge economy. See Duby (chapter 16) and Mathews and Hu (chapter 5).

[14] Romer (2000) discusses the gains from subsidizing S&T education through scholarships.

tions but also as centers of research. This strategy complements pressures arising from globalization. In the process, public universities are gaining more autonomy, which private universities have always enjoyed. This freedom opens opportunities for a more aggressive pursuit of reforms to attract better students,[15] to expand R&D, to explore new sources of financing, and to acquire the knack for entrepreneurship. For universities, most of which have no tradition of entrepreneurship and limited managerial capacity, these additional responsibilities entail learning corporate skills, providing new incentives, and introducing new courses. Guided by recently appointed presidents (chapter 12 by Wong), the National University of Singapore and the Korea Advanced Institute of Science and Technology have taken the lead.

The state has also moved in a number of countries—starting with the United States—to make the development and patenting of technologies, as well as the licensing of their use, attractive for university researchers and universities by giving researchers the intellectual property rights over scientific findings arrived at with the use of public funds. Where the patenting system functions effectively—that is, where the costs of applying for and maintaining a patent are affordable, turnaround is reasonably fast, and intellectual property rights are given a decent degree of protection by the courts, again at a cost that the bulk of patentees can manage—the incentives to push scientific research toward patentable discoveries that can have a commercial future has increased. Although the Bayh-Dole Act was not responsible for the quickening of innovation, it certainly did stimulate patenting and paved the way to greater commercialization (chapter 10 by Mowery; Sampat 2006). Sampat (2006) observes that patenting and licensing are among the less important channels for technology transfer, that there is little evidence of insufficient technology dissemination from universities before Bayh-Dole, and that the net effect of Bayh-Dole on innovation is unclear. Geuna and Nesta (2006) further point out that university patenting in Europe and the United States was already ongoing and did not require the incentives provided by Bayh-Dole. Increased patenting from the 1980s had more to do with opportunities in the biomedical, electronics, and IT fields than with policy or legislation.

National governments can further influence the commercial orientation of universities by developing science parks in the vicinity of universities,

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[15] Such opportunities include attracting researchers who have trained overseas and have acquired research and teaching experience in Western universities (Saxenian 2006; Sigurdson 2005; Yusuf and others 2003).

often with the participation of local developers, and by spurring university spinoffs and start-ups with university connections directly through their policies on venture capital and more indirectly through their rules governing capital markets and the launching of initial public offerings (Baxter and others 2005).

It is less easy to generate the demand for UILs from the business sector by way of national policies, unless the public resources made available to firms for research through tax exemptions and credits or through direct grants or government purchase contracts are earmarked. What governments have done is to markedly improve the tax credits for R&D and to provide research money for developing new technologies.[16] Schemes such as the U.S. Small Business Innovation Research Program, requiring a number of government departments to allocate funds for R&D grants to smaller firms, have won support at home and abroad (Toole and Czarnitzki 2005).[17] Moreover, as firms have moved to moderate their own basic research and focus their own efforts, they have come to rely more on university-based researchers in emerging fields where interdisciplinary expertise is required, such as nanotechnology. National governments, as in China, are also attempting to multiply UILs by measuring the performance of universities with reference to the number of spinoffs or start-ups, among other indicators (Wu, chapter 11). Where this strategy works, many of the emerging firms are likely to maintain their links with the university, particularly in fields such as biotechnology that are more dependent on advances in basic science and on tacit scientific knowledge.

Subnational Policies

In countries large and small, the policies of the central government with respect to UILs are complemented by those of subnational authorities, whether provincial, county, or municipal. In Brazil, Canada, China, and the United States, for example, this decentralization sets the stage for fierce competition to attract and retain industries, especially those that generate numerous localized links, employment, exports, and added value. Not infrequently, the favored industries are technology and skill intensive. For them, a research-oriented university with strong science

[16] In the United Kingdom, in 2005, the R&D tax credit amounted to £500 million. Defense-related R&D was another £2 billion (see chapter 4 by Hughes).

[17] Toole and Czarnitzki (2005) find that the Small Business Innovation Research Program has stimulated entrepreneurship by university-based researchers, for example, and that firms that graduate from the program have an easier time finding follow-on funding from venture capitalists.

and professional programs can be a major attraction, because it can be a source of both trained staff members and of knowledge spillovers. For example, researchers in the university can assist with the refinement of existing technologies and the development of new techniques. Whether UILs are sparse or dense and what mix develops of such links depend on many factors, including the technology bias of the firms, their strategy with respect to technology, and their readiness to pursue innovation in an open manner by using local talent. The quality of university researchers, their ability to collaborate with firms, and university policies all modulate outcomes. However, in a decentralized milieu, subnational policies can affect the proliferation and the fruitfulness of UILs in two ways if governments come to view universities as sources of growth and as potential foci of industrial clusters. First, provincial and municipal policies concerning universities can affect the quality and orientation of research. Second, these policies can catalyze links and strengthen the incentives for UILs.

Whether subnational governments can harness universities for the purpose of local development depends at the very outset on the university's location and potential. The vast majority of universities are not in a position to engage in research or to forge links with industry other than those created by individual consulting assignments. They are too small or have too shallow a pool of research talent to create viable, effectively managed teams, or they are focused on teaching. Those located in smaller, sometimes remote towns and cities can be further disadvantaged, because few industries come to such cities.[18] A globalizing economy has ambiguous implications for location. Being at or near an existing or budding industrial hub remains a significant advantage. This location also affects the quality of the students and faculty. Being in a major metropolitan area with a diverse base of economic activities that can give rise to demand for research services from universities also is a significant plus.[19] Put differently, subnational governments can leverage the assets of a university if location and reputation suggest that providing incentives will attract industry that could spiral into a major cluster or several linked miniclusters. However, because of advances in IT and the greater readi-

[18] Such universities (and the cities in which they are located) also have difficulty retaining their best graduates in teaching or research activities. Very often the most promising candidates migrate to larger cities with wider opportunities.

[19] Yusuf and Nabeshima (2006) examine the development of creative and high-tech industries in major East Asian cities and show how these industries have benefited from and drawn on resources of universities.

ness of MNCs to look farther afield for research support, long-distance collaboration among researchers and UILs is becoming more common. Relative isolation is no longer as much a drawback for universities as it once was (Behrens and others 2006).

When a suitable candidate research university (or universities) is identified, subnational governments have a small handful of policy tools. They can provide research grants and help finance specialized research facilities or institutes to undertake activities with probable spillovers and links to businesses.[20] The authorities in Shanghai have been especially aggressive in this regard, but with financing comes much closer oversight of university activities (chapter 11, Wu). Subnational governments can create intermediary organizations or industrial extension agencies to bridge the gulf between university researchers and firms, particularly small firms that suffer from information gaps and have difficulty accessing and using research. State or municipal governments can broker alliances between university research departments and firms using regional or national bodies as matchmakers, and they can try to cement the alliances with an infusion of funds. They can use state or quasi-state agencies to provide venture capital for university spinoffs. State governments can finance incubators and can offer the university supplementary earmarked funding for research, conditioned on the university's achieving a certain level of consulting contracts, spinoffs, or start-ups by university faculty or graduates. Numerous examples of such bodies in Ontario, Canada; in India; in Singapore; and in the United Kingdom are discussed by Hughes (chapter 4), Wolfe (chapter 7), and Wright (chapter 9).

Last but not least, state or municipal authorities, possibly in partnership with local developers or associations, can provide the serviced land and infrastructure adjacent to universities to attract firms, to subsidize the training of industrial workers, and to extend tax incentives to firms that locate there.[21] They can work with municipal authorities to improve public services and amenities in the urban area, which are essential for attracting and retaining talented knowledge workers (Florida 2002, 2005).

Subnational governments in Europe and North America, as well as in Brazil, China, India, and Japan, are using a mix of such policies to cultivate UILs and make universities into magnetic poles for growth. Although

[20] Jenkins, Leicht, and Wendt (2006) provide a detailed account of the incentives offered by subnational governments in the United States to attract and promote industry.

[21] Indergaard (2004) describes instances of such collaboration with respect to the University of Texas in Austin and Silicon Alley in New York.

experience is accumulating, as yet no winning recipe is clear. The policy options for creating links with second-tier provincial universities are circumscribed by the depth of talent that can be mobilized by these universities in specific fields, their capacity to offer interdisciplinary breadth, and the globalization of research noted earlier, which has affected even the leading Dutch and Swiss universities. Moreover, the transaction costs for small and medium enterprises are such that their ability to engage universities is unlikely to change. Policies can contribute; however, the university's reputation and quality remains an important starting point.

Corporate Policies

National and subnational governments are the principal architects of the national innovation strategy. They set the parameters for higher education, and they craft the incentive mechanisms as well as the institutions that influence business decisions regarding where to locate, what to produce, how much to spend on research, and the degree to which firms link up with universities in developing technologies. Government policies strongly affect the potential supply of research and technological inputs from universities. To a lesser degree, they also impinge on the demand for the services available from universities. But the decision to establish links ultimately rests with the firms themselves.[22] The recent experience of the industrial countries regarding the interaction between firms and universities is quite mixed, with no clear trends apparent.

As noted previously, firms are more aware of the gains in competitiveness from innovation and are sensitive to the high returns from R&D.[23] However, much of the R&D outlay is by large companies. Smaller companies invest little in research, although they do spend on testing, quality control, and incremental innovation—whether done in-house, done together with suppliers, or—more often—outsourced to research labs and consultants.[24] The larger firms have begun narrowing their own research efforts and making greater use of alliances and collaborative arrangements, taking over firms that have introduced new technologies, using

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[22] The motivations of firms are various, such as strengthening skills and gaining access to the university's facilities (Santoro and Chakrabarti 2002).

[23] Social returns of up to 90 percent have been estimated. Private returns are lower, usually 20 percent or less, but still respectable.

[24] Small U.K. firms do not regard universities as a main source of knowledge, whereas small U.S. firms regard universities as an effective and useful source (see chapter 4 by Hughes).

outsourcing arrangements, and instituting UILs. Thus, in the interests of reducing costs, tapping a wider range of disciplines, canvassing a variety of technological options, and spurring multiple competing research initiatives, firms are moving toward open innovation practices (Chesbrough 2003).[25] Relative to firms in the United Kingdom, U.S. firms place more emphasis on an open innovation approach. One result of this emphasis that coincides with the efforts made by universities themselves is some increase in links between firms and university faculties.

In Japan, companies prefer informal ties with universities. Corporate researchers coauthor papers with university faculty members, spend time working at university laboratories, do joint projects with university researchers, and enter into consulting arrangements with university-based researchers. Typically, the UILs are with the leading large universities and research centers; firms are ready to seek out the best academic talent from across the country rather than limiting themselves to universities close to their own headquarters or research facilities.

At the other extreme is the United States, where UILs cover the entire spectrum but formal contractual arrangements with universities are common, as are outsourcing of entire research projects to university labs, joint research agreements, and individual contracts with key researchers. Europe falls somewhere in the middle. In the Republic of Korea and India, small firms have virtually no contact with universities as far as research is concerned, but they may seek help for the purpose of troubleshooting from individual researchers. In those countries, links, mostly of a localized nature, are emerging between some of the larger companies in the technology sectors and elite universities. A similar tendency is materializing in China as a result of a determined push by governments to induce both universities and state enterprises to cooperate in developing technologies.

So far, the evidence from industrial countries indicates that the large MNCs are most likely to tap the research potential of universities.[26] The best equipped to do so, as shown by Kodama, Kano, and Suzuki (chapter 15), are MNCs that are actively seeking specific kinds of results that

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[25] Firms especially rely on their internal capabilities for their innovation. Other typically cited sources are customers, suppliers, competitors, and universities, in that order (see chapter 4 by Hughes).

[26] Research on Belgian firms offers support. Generally, larger firms and firms in the pharmaceutical and chemical subsectors are more likely than firms in other subsectors to establish research ties with universities (Veugelers and Cassiman 2005).

complement their own research. As noted by Cohen and Levinthal (1990) and several contributors to this volume, the absorptive capacity of the firm—its cognitive preparedness to search for, perceive, and exploit research findings—is essential to the germination of advantageous links (chapter 3 by Foray; Boschma 2005). MNCs banking on innovation to sustain competitiveness have the information, the finances, the organizational capacity to manage a multifaceted research program, and the commitment to routinized innovation that can induce technology links with universities. But because MNCs increasingly have global reach and information on the research potential of universities and institutes, they are more likely to seek the most cost-effective and technologically fruitful arrangements and not to limit their search to institutions in their own countries or in the proximity of their main offices. When overtures to universities by firms do not elicit positive responses, firms are likely to shop elsewhere. As Brimble shows in chapter 17, Thai universities have allowed opportunities for UILs to slip away because of a lack of proactive measures, entrepreneurship, organizational skills, and government support.

If the life sciences, nanotechnology, and other fields whose development is paced by basic science continue to flourish, the elite universities and research institutes may be better placed to take a lead than most corporate labs. In fact, many biotechnology firms are spinoffs, have been started by university researchers, or are based on the findings of research at a university with which they are frequently associated.

Policies of Universities

Although most universities in industrial and industrializing countries still have few formal links with the business sector, the economic, technological, and business milieus are changing, and with them the attitudes of university administrators. Many more universities, or at least researchers in tertiary institutions, will be trying harder to commercialize scientific discoveries and to connect with the business world, as in China, Singapore, and Taiwan (China). Traditionalists might not view this development as healthy, and if UILs divert time, resources, and attention from teaching, they could have drawbacks. But no convincing set of reasons exists demonstrating why they should. Some of the world's finest teaching institutions are also leaders in the world of research. And many believe that teaching and research go hand in hand. Schools with strong research programs attract the best faculty and students. In turn, through their entrepreneurship and innovations, they can galvanize the local urban economies, thereby generating job opportunities and links with universities that will further enlarge the university talent pool (Glaeser and Berry 2006).

Although generalizations are difficult, the underlying trend is toward greater autonomy for public universities and, overall, toward greater competition among universities for students, resources, and star faculty members—again, on balance, a healthy development. This competition is rapidly acquiring a global dimension as students and academics become more mobile and perceive a wider range of options. In addition, universities, behaving a little like MNCs, are setting up satellite campuses in other countries and are entering into partnerships, leveraging their brand names and human capital to the hilt (Olds forthcoming). The University of Nottingham has set up a campus in Ningbo, China, and INSEAD, as well as other schools, has established a satellite in Singapore.

Many universities also are coming to realize that with recurrent expenditures mounting, student demographics changing, and salaries demanded by able teachers and researchers on the rise, a pure teaching function might prove to be unsustainable. In fact, one of the biggest problems confronting universities vying for the best research talent in Europe and Japan is that university salaries often are below salaries for similar jobs in industry, and university buildings and infrastructure are of lower quality. Salaries are a constraint in China as well (chapter 11 by Wu). Closer relations with the business sector may be unavoidable. Thus, university policies are in transition and seeking a compass that will reconcile past experience with current aspirations.

Where feasible, academics depending on discipline have attempted to supplement their salaries with consulting. This situation is even truer in industrializing countries such as Thailand and Vietnam, where salaries are low and consulting is almost a necessity. When teaching and administrative responsibilities permit, more schools have begun encouraging faculty members to consult and bid for research grants. In fact, the performance and worth of an academic in some institutions is being measured with reference not just to teaching skills and publications—although these continue to command precedence—but also to earnings from consulting and resources mobilized from external sources (chapter 11 by Wu).

Entrepreneurial universities that actively seek connections with the business sector are adopting a number of policies. U.S. universities took the lead, and some have now accumulated decades of experience (chapter 10 by Mowery).[27] Giving faculty time and facilities to conduct research, encouraging consulting activities, and garnering research funding were among the initial steps.[28] They paralleled the growth of graduate study programs that both stimulated research activity and provided the low-cost human capital to sustain it. For universities in the United States, which embraced research, government sponsorship of research and graduate study during the Cold War provided a great boost and created both an institutional and a physical infrastructure for such research within universities. It also gave rise to a scientific culture that, through specialized journals, the peer review process, conferences, and frequent scholarly intercourse and collaboration, has helped make the research endeavor unusually productive.[29] Financing from the government, the corporate sector, and foundations facilitated the research, but it was a congeries of substantially autonomous university policies that fashioned the environment in which scientific investigation of the highest order could flourish. In a different manner, Japanese academics from elite universities have been as active as their American counterparts. Kodama and Suzuki (forthcoming) show from a tabulation of papers coauthored by academics with corporate researchers and of corporate patents citing academic researchers that the links through these channels are robust, with a brisk two-way traffic of ideas. This environment, this tradition, and this standard of excellence are what late starters like China, Singapore, and Taiwan (China), as well as European countries, are trying to embed in their own universities in short order without the benefit of the talent that the United States has received from Europe and, in more recent years, from Asia. China and India might benefit from their size, the heterogeneity of their universities, and decentralization if central and lower-level governments permit active competition.

The more venturesome universities have attempted to promote and capitalize on in-house research by setting up technology licensing offices

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[27] One example of a recent success is the multiplication of biotech firms in the vicinity of Yale University in New Haven, Connecticut. This growth was largely the result of proactive university policies, including the strengthening of the office of cooperative research (Breznitz 2005).

[28] Lim (1999) describes the incentives and flexibility enjoyed by the faculty at MIT. The National University of Singapore is also working with a package of similar incentives to motivate an international body of researchers, 80 percent of whom are foreigners.

[29] On institution of the peer review process for assessing quality and for allocating research funding in the United States, see Etzkowitz and Leydesdorff (2000). Lim (1999) notes the weaknesses of such a peer review mechanism in Korea.

to patent findings and solicit license fees and royalties (chapter 12 by Wong). A tiny number of universities, such as Stanford and MIT, as well as the California state universities, reap a few million dollars per year from this effort (chapter 10 by Mowery). For others, the earnings often do not cover costs. However, DeVol and Bedroussian (2006) find that returns from research and technology licensing offices (TLOs) are becoming substantial.

Universities have actively sought ties with business firms, especially those in their vicinity and those established by alumni. Stanford, which is something of a role model, has generated knowledge exchanges and formal links by arranging for experts in the business community to teach courses and by tailoring courses and whole institutions for local industries. This service function has succeeded in generating a substantial flow of resources to Stanford from businesses in Silicon Valley and elsewhere.

Many large elite universities have set up incubators to nurture firms that can be spun off, sometimes with the help of venture capital provided by the university or with the help of university connections. Except in quite rare cases, few of these ventures provide the university with large returns on invested capital, but some do, and spinoffs from Tsinghua University and Peking University in Beijing are a major source of revenues for their parent organizations (chapter 11 by Wu; Chen and Kenney forthcoming).

An adjacent science park generally requires the backing of subnational or national governments; however, scores of universities throughout the industrial world are helping develop industrial clusters in such customized parks. In India alone, well over a dozen software parks operate in the vicinity of the nation's premier technology institutes.[30] The necessary conditions for growing a cluster are now reasonably well codified. Singapore, for instance, is attempting to fulfill all of these conditions in its efforts to build a viable biotech cluster near the National University of Singapore (Yusuf and Nabeshima 2006), but the necessary conditions to achieve success are elusive. So cluster development is a chancy business, and many of the science parks are financial failures. Numerous examples of such failed attempts exist in China.

These initiatives reflect only some of the policies being pursued by universities to build bridges to the business sector. The most entrepreneurial universities are constantly experimenting with new links, working

[30] In India, National Chemical Laboratories, which is the country's leading research center, has no spinoffs yet (chapter 13 by Basant and Chandra).

with nonprofit groups, MNCs, local government, and consortia of small firms. This activity is raising their profile and perhaps paving the way for a substantially larger role in what is shaping up as a global innovation system. If innovation is likely to be the principal driver of growth, universities could emerge as the most dynamic transnational entities and a commercial force in their own right. But it must be underscored that the term *entrepreneurial research university* applies so far to a select few in any country. Size, location, and circumstances circumscribe the role of most tertiary-level institutions. Even the largest ones are hobbled by inertia, tradition, and poor management. Nevertheless, change is beginning to penetrate further than was imaginable two decades ago.

Conclusion

UILs are here to stay. How much they proliferate and what their effect will be on technological capability will depend in large part on the policies adopted by the four principal players. As indicated in this chapter, those policies are still evolving; participants are groping their way forward, guided by only the broadest of objectives and a relatively limited fund of past experience. Public officials and universities the world over have been greatly influenced by the experience and example of Stanford, MIT, and the University of California, San Diego, and many economies in Asia and Europe are attempting to replicate those examples—notably China, Malaysia, Singapore, and Taiwan (China). Industrial countries are coming to view universities as vehicles for accelerating technological advance to enable them to stay ahead of competitors from the middle-income countries. Late starters view research-oriented universities as vehicles for catching up, technologically, with the frontrunners.[31] Expectations are building, varying combinations of policies are being devised, and governments are committing large sums to enhance innovation capability. Two imponderables exist here. One is whether through links with the business sector some universities can actually be converted into engines for promoting technological change without being seriously deflected from their primary missions. It is an open question also whether their direct contribution to technology development and innovation, which has been limited thus far, can be appreciably raised.

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[31] In Gerschenkron's (1962) terms, they are the modern-day versions of stage-skipping innovations (chapter 5 by Mathews and Hu).

Second, even if measures to significantly raise the level of R&D in universities can be made to work—and it will be difficult—this accomplishment need not be matched by demand from business firms, and it might not lead to spinoffs from the university or to start-ups. The larger firms that are most partial to university research may not have the appetite for more, and smaller and medium-sized firms might continue to shy away in the absence of effective intermediary institutions that serve as bridges between universities and firms.

The pressures unleashed by globalization and reinforced by policies could well spur innovative effort in universities and generate the demand for it among firms. Outcomes are hard to predict. For the moment, what we have in the chapters that follow is a wealth of examples of policies being tested. The results are beginning to trickle in, but the worth of these policies remains to be determined. Many countries are pinning their hopes on the success of these policies.

References

Agarwal, Rajshree, and Michael Gort. 2001. "First-Mover Advantage and the Speed of Competitive Entry, 1887–1986." *Journal of Law and Economics* 44 (1): 161–77.

Baxter, Christie, Peter Tyler, Barry Moore, Nicky Morrison, Rob McGaffin, and Monica Otero-Garcia. 2005. *Enterprising Places: Sustaining Competitive Locations for Knowledge-Based Business*. Cambridge, U.K.: Cambridge–MIT Institute.

Behrens, Kristian, Carl Gaigne, Gianmarco I. P. Ottaviano, and Jacques-François Thisse. 2006. "Is Remoteness a Locational Disadvantage?" *Journal of Economic Geography* 6 (3): 347–68.

Berger, Suzanne. 2005. *How We Compete*. New York: Doubleday.

Boschma, Ron A. 2005. "Proximity and Innovation: A Critical Assessment." *Regional Studies* 39 (1): 61–74.

"Brains Business: A Survey of Higher Education, The." 2005. *Economist*. September 10.

Breznitz, Shiri. 2005. "From Ivory Tower to Industrial Promotion: The Case of Yale University and the Biotechnology Cluster in New Haven, Connecticut." STE-WP-28, Samuel Neaman Institute, Haifa, Israel.

Business–Higher Education Forum. 2001. *Working Together, Creating Knowledge: The University-Industry Research Collaboration Initiative*. Washington, DC: Business–Higher Education Forum.

Carlsson, Bo. 2006. “Internationalization of Innovation Systems: A Survey of the Literature.” *Research Policy* 35 (1): 56–67.

Chen, Kun, and Martin Kenney. Forthcoming. “Universities/Research Institutes and Regional Innovation Systems: The Cases of Beijing and Shenzhen.” *World Development*.

Chesbrough, Henry William. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business Review Press.

Cohen, Wesley M., and Daniel A. Levinthal. 1990. “Absorptive Capacity: A New Perspective on Learning and Innovation.” *Administrative Science Quarterly* 35 (March): 128–52.

DeVol, Ross, and Armen Bedroussian. 2006. *Mind to Market: A Global Analysis of University Biotechnology Transfer and Commercialization*. Santa Monica, CA: Milken Institute.

Etzkowitz, Henry. 2002. “Bridging Knowledge to Commercialization: The American Way.” Science Policy Institute, State University of New York, Purchase, NY.

Etzkowitz, Henry, and Loet Leydesdorff. 1997. *Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations*. New York: Continuum.

———. 2000. “The Dynamics of Innovation: From National Systems and ‘Mode 2’ to a Triple Helix of University-Industry-Government Relations.” *Research Policy* 29 (2): 109–23.

Etzkowitz, Henry, Andrew Webster, Christiane Gebhardt, and Branca Regina Terra Cantisano. 2000. “The Future of the University and the University Future: Evolution of Ivory Tower to Entrepreneurial Paradigm.” *Research Policy* 29 (2): 313–30.

Feldman, Maryann, and Pierre Desrochers. 2004. “Truth for Its Own Sake: Academic Culture and Technology Transfer at Johns Hopkins University.” *Minerva* 42 (2): 105–26.

Florida, Richard. 2002. *The Rise of the Creative Class: And How It’s Transforming Work, Leisure, Community, and Everyday Life*. New York: Basic Books.

———. 2005. *The Flight of the Creative Class: The New Global Competition for Talent*. New York: Harper Collins.

Friedman, Thomas. 2006. *The World Is Flat: A Brief History of the Twenty-First Century*. New York: Farrar, Straus and Giroux.

Galison, Peter, and Bruce Hevly. 1992. *Big Science: The Growth of Large-Scale Research*. Palo Alto, CA: Stanford University Press.

Gerschenkron, Alexander. 1962. *Economic Backwardness in Historical Perspective*. Cambridge, MA: Belknap Press.

Geuna, Aldo, and Lionel J. J. Nesta. 2006. "University Patenting and Its Effects on Academic Research: The Emerging European Evidence." *Research Policy* 35 (6): 790–807.

Glaeser, Edward, and Christopher Berry. 2006. "Why Are Smart Places Getting Smarter." Rappaport Institute/Taubman Center Policy Brief 2006-2, John F. Kennedy School of Government, Harvard University, Cambridge, MA. http://www.ksg.harvard.edu/rappaport/downloads/policybriefs/brief_divergence.pdf.

Gomes-Casseres, Benjamin, Adam B. Jaffe, and John Hagedoorn. 2006. "Do Alliances Promote Knowledge Flows?" *Journal of Financial Economics* 80 (1): 5–33.

Hall, Bronwyn, and Jacques Mairesse. 2006. "Empirical Studies of Innovation in the Knowledge Driven Economy." NBER Working Paper 12320, National Bureau of Economic Research, Cambridge, MA.

Hambling, David. 2005. *Weapons Grade*. New York: Carroll and Graf Publishers.

Indergaard, Mich. 2004. *Silicon Alley (Cultural Spaces)*. New York: Taylor and Francis.

Jenkins, J. Craig, Kevin Leicht, and Heather Wendt. 2006. "Class Forces, Political Institutions, and State Intervention: Subnational Economic Development Policy in the United States, 1971–1990." *American Journal of Sociology* 111 (4): 1122–80.

Kim, E. Han, Adair Morse, and Luigi Zingales. 2006. "Are Elite Universities Losing Their Competitive Edge?" NBER Working Paper 12245, National Bureau of Economic Research, Cambridge, MA.

Kimura, Yui. 1997. "Technological Innovation and Competition in the Japanese Semiconductor Industry." In *Innovation in Japan*, ed. Akira Goto and Hiroyuki Odagiri, 121–158. New York: Oxford University Press.

Kodama, Fumio, and Jun Suzuki. Forthcoming. "How Japanese Companies Have Used Scientific Advances to Restructure Their Business: The Receiver-Active National System of Innovation." *World Development*.

Lim, Youngil. 1999. *Technology and Productivity: The Korean Way of Learning and Catching Up*. Cambridge, MA: MIT Press.

Lucas, Robert. 1989. "On the Mechanics of Economic Development." *Journal of Monetary Economics* 22 (1): 3–42.

MacGarvie, Megan, and Jeffrey Furman. 2005. "Early Academic Science and the Birth of Industrial Research Laboratories in the U.S. Pharmaceutical Industry." NBER Working Paper 11470, National Bureau of Economic Development, Cambridge, MA.

Mowery, David, and Nathan Rosenberg. 1998. *Paths of Innovation: Technological Change in 20th-Century America*. New York: Cambridge University Press.

Olds, Kris. Forthcoming. "Global Assemblage: Singapore, Western Universities, and the Construction of a Global Education Hub." *World Development*.

Romer, Paul M. 1989. "Human Capital and Growth: Theory and Evidence." NBER Working Paper 3173, National Bureau of Economic Research, Cambridge, MA.

———. 2000. "Should the Government Subsidize Supply or Demand in the Market for Scientists and Engineers?" NBER Working Paper 7723, National Bureau of Economic Research, Cambridge, MA.

Ruegg, Walter. 2004. *Universities in the Nineteenth and Early Twentieth Centuries (1800–1945): Volume Three*. Cambridge, U.K.: Cambridge University Press.

Sampat, Bhaven N. 2006. "Patenting and U.S. Academic Research in the 20th Century: The World before and after Bayh-Dole." *Research Policy* 35 (6): 772–89.

Santoro, Michael, and Alok Chakrabarti. 2002. "Firm Size and Technology Centrality in Industry-University Interactions." *Research Policy* 31 (7): 1163–80.

Saxenian, AnnaLee. 2006. *The New Argonauts*. Cambridge, MA: Harvard University Press.

Schwartz, Evan I. 2004. *Juice: The Creative Fuel That Drives World-Class Inventors*. Cambridge, MA: Harvard Business School Press.

Sigurdson, Jon. 2005. *Technological Superpower China*. Northampton, MA: Edward Elgar.

Sutz, Judith. 1997. "The New Role of the University in the Productive Sector." In *Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations*, ed. Henry Etzkowitz and Loet Leydesdorff, 11–20. New York and London: Continuum International Publishing Group.

Tadmor, Zehev. 2006. "Redefining Engineering Disciplines for the Twenty-First Century." *Bridge* 36 (2): 33–37.

Toole, Andrew, and Dirk Czarnitzki. 2005. "Biomedical Academic Entrepreneurship through the SBIR Program." NBER Working Paper 11450, National Bureau of Economic Research, Cambridge, MA.

Trumbull, Gunnar. 2004. *Silicon and the State: French Innovation Policy in the Internet Age*. Washington, DC: Brookings Institution Press.

Veugelers, Reinhilde, and Bruno Cassiman. 2005. "R&D Cooperation between Firms and Universities: Some Empirical Evidence from Belgian Manufacturing." *International Journal of Industrial Organization* 23 (5–6): 355–79.

Yamamoto, Shinichi. 1997. "The Role of the Japanese Higher Education System in Relation to Industry." In *Innovation in Japan*, ed. Akira Goto and Hiroyuki Odagiri, 294–307. New York: Oxford University Press.

Yusuf, Shahid, M. Anjum Altaf, Barry Eichengreen, Sudarshan Gooptu, Kaoru Nabeshima, Charles Kenny, Dwight H. Perkins, and Marc Shotten. 2003. *Innovative East Asia: The Future of Growth*. Washington, DC: International Bank for Reconstruction and Development.

Yusuf, Shahid, and Kaoru Nabeshima. 2006. *Postindustrial East Asian Cities*. Washington, DC: World Bank.

PART I

UIL-Related Policies of National Governments

CHAPTER 2

Notes on UIL-Related Policies of National Governments

Luc Soete

In their relative success and failure in attempting to enhance university-industry links (UILs), the various European policies provide some interesting insights for countries at different levels of development. After all, the recent endogenous growth and innovation literature has returned to the forefront the importance for development of industrial policy on innovation (as recently emphasized in Aghion and Howitt 2006). That literature has, as yet, not made the connection with the more detailed discussion surrounding UILs, but it offers many opportunities to do so. Thus, for high-income countries such as the European ones, the current innovation–endogenous growth debate centers primarily on the sustainability of Schumpeterian "creative destruction" within environments that increasingly give a premium to insiders, to security and risk aversion, and to the preservation of existing competitive strengths and the maintenance of income and wealth. Among other factors, this environment is reflected in high entry barriers, lack of competition in many high-tech sectors, a general lack of competition in higher education, and lack of mobility of scientists and engineers. All those issues will be central concerns in various attempts to enhance UILs. In emerging economies, by contrast, the innovation challenge appears to coincide with policies of the "backing winners"[1] type, which are more akin to industrial science and technology policy. Under this more traditional, industrial science and technology perspective, UILs are likely to play a rather different role.

From this perspective, the European policy experiences might be of particular relevance to current debates within emerging economies about appropriate national innovation policies. At the same time and viewing innovation development challenges from a global perspective, the new Schumpeterian growth models also provide interesting insights into possible macroeconomic creative destruction features of innovation-based growth—the way in which most quality-improving innovations will ultimately replace existing products, rendering them obsolete, thus continuously putting into question international competitiveness. If only the effect of information and communication technology on opening up world markets and bringing about global price transparency is considered, the creative destruction features associated with new entry would play a significant role in thinking about knowledge-based growth and development opportunities. These models do fit rather nicely my own personal convictions with respect to development opportunities associated with technological leapfrogging and possible limited windows of entry as argued in some of my own earlier development writings (Soete 1981, 1985) and those with Carlota Perez (Perez and Soete 1988).

What Can We Learn from European National Policies with Respect to Research, Innovation, and UILs?

Over the past 10 to 15 years, a major shift has taken place in understanding of the relationships between research, innovation, and socioeconomic development. Single-factor explanations of either the technology-push or the demand-pull kind have by and large disappeared. Instead, economic growth and well-being are now widely recognized as being founded on a well-functioning knowledge and innovation system in which all actors, both the typical knowledge-creation actors (such as universities and public research organizations) and private firms, perform well. The concept

[1] This view of the philosophy and aims of innovation policies differing among countries according to their level of development has become very popular in the endogenous growth literature (see Aghion and Howitt 2006).

of a national (or regional) innovation system emerged in the late 1980s. It incorporated all actors and activities in the economy involved in knowledge production. It emphasized the national institutional framework within which firms, universities, and other organizations operated and the links between them as essential factors in explaining the differences in the speed, extent, and success by which innovations were introduced and diffused in the economy, whether nationally or regionally.

The common feature of all such systems—regional, national, or even transnational—was, of course, the fact that firms rarely if ever innovated alone. From a voluminous literature on innovation studies, interaction and cooperation between the innovating firm and its external environment appeared to be a constant, which in the optimal case would lead to a virtuous learning circle of better exploitation of available knowledge, often located within local knowledge institutions such as universities. At the same time, the fact that the knowledge and innovation systems of countries at similar levels of development, such as the European Union (EU) member countries, showed marked differences associated with their individual paths of specialization in production had obvious policy implications and became the basis of very different sets of innovation policies in different countries. As a result, a new category of policy research emerged, addressing the differences between countries and regions, arguing that comparative analyses of such systems of innovation would allow one to identify which elements of the system would be most subject to inertia in particular country or regional settings so that particular deficiencies could be addressed. Hence, many authors of literature addressing national systems of innovation, such as Charles Edquist, Christopher Freeman, Bengt-Åke Lundvall, and Richard Nelson, would speak of the simultaneous and interrelated evolution of knowledge, innovations, organizations, and institutions. From a systemic policy perspective, the weakest link is often the most critical one for economic growth and development—and hence also for policy intervention.

The idea that something can be learned from institutional arrangements and policies in other, more advanced environments, as exemplified today in the European obsession with the knowledge gap with the United States, and that systematic comparative studies are a useful tool in this respect is not a new one. Alexander Gerschenkron (1962) pioneered this kind of comparative country study. As he pointed out, some countries are at the technological frontier, whereas others lag far behind. Although the technological gap between the frontier country and the laggard would represent great promise for the latter (a potential for higher growth through imitating frontier technologies), various problems also exist that would prevent backward countries from reaping the potential benefits to the full. Gerschenkron actually argued that if one country succeeded in embarking on an innovation-driven growth path, others might find it increasingly difficult to catch up. His favorite example was Germany's attempt to catch up with the United Kingdom a century ago. When the United Kingdom industrialized, technology was relatively labor intensive and small scale. But in time, technology became more capital and scale intensive, so when Germany entered the scene, the conditions for entry had changed considerably. Because of this change, Gerschenkron (1962) argued, Germany had to develop new institutional instruments for overcoming these obstacles, above all in the financial sector. He held these experiences to be valid also for other technologically lagging countries.[2]

In this context, Moses Abramovitz (1986) introduced the notions of technological congruence and social capability to discuss what he called the "absorptive capacity" of latecomers. The concept of *technological congruence* referred to the degree to which leader and follower country characteristics were congruent in areas such as market size and factor supply. The concept of *social capability* pointed to the various efforts and capabilities that backward countries used to catch up, such as improving education, infrastructure, and technological capabilities—research and development (R&D) facilities and the like. He explained the successful catching up of Western Europe vis-à-vis the United States after World War II as the result of both increasing technological congruence and improved social capabilities. As an example of the former, he mentioned explicitly how European economic integration led to the creation of larger and more homogeneous markets in Europe, facilitating the transfer of scale-intensive technologies initially developed for U.S. conditions. Improved social capabilities were reflected in such other factors as the general increase in educational levels, the rise in the share of resources devoted to public and private sector R&D, and the success of the financial system in mobilizing resources for change. What Abramovitz did not cover were the successes or failures of the links between those various features of technological congruence and social capability.

Those links, however, appear to be important in explaining the systemic success or failure of science, technology, and innovation policies

[2] For a more in-depth analysis of these historical contributions to modern catching-up growth theory, see Fagerberg (2002).

in various European countries. Let me briefly report here on some work carried out for the European Commission (Soete and others 2002) that attempted to identify the strengths and weakness of such links.[3] The core of this analysis hinges on the notions developed by Abramovitz and subsequently used in many growth and development studies. Although the analysis was carried out at the national level, it can easily be repeated at the regional level.

At the outset, four factors appear essential for the functioning of a national system of innovation. First is the investment of the country in *social and human capital*: the cement, one may argue, that holds the knowledge and innovation systems together. This capital is incorporated in a number of knowledge-generating institutions in the public as well as the private sector, such as universities, polytechnics, and other vocational training schools. The EU as a whole currently spends 1.2 percent of its gross domestic product (GDP) on such higher-education institutions; the United States spends more than double that figure: roughly 2.6 percent of its GDP. At the same time, the EU has more or less the same number of higher-education establishments, about 4,000. Not surprisingly, the large majority of European universities find themselves in a sometimes dramatically underfunded position, with poor teaching and research facilities and continuous emigration of their biggest talents.

Higher education is itself crucial for the continuous feeding of fundamental and applied research. Many new growth models have attempted to build such effects in a more complex fashion, giving prime importance not just to education itself, but also to its by-products, such as research and innovation. The second central node of any system of innovation is, hence, not surprisingly the *research capacity* of a country or region and the way it is closely intertwined with the country's higher-education system. From a typical national innovation system perspective, such close interaction appears important; from an international perspective, the links might be much looser, with universities and research institutions being capable of attracting talent worldwide.

The third node holding knowledge together within the framework of a national system of innovation is, maybe surprisingly, geographical proximity, which leads to *technological and innovative performance*. The

[3] A lot of research has also been carried out for the EU on the nature of university-industry links using various bibliometric and other innovation indicators. I will not elaborate here on those numerous studies, some of which MERIT (Maastricht Economic and Social Research and Training Centre on Innovation and Technology) has been involved in.

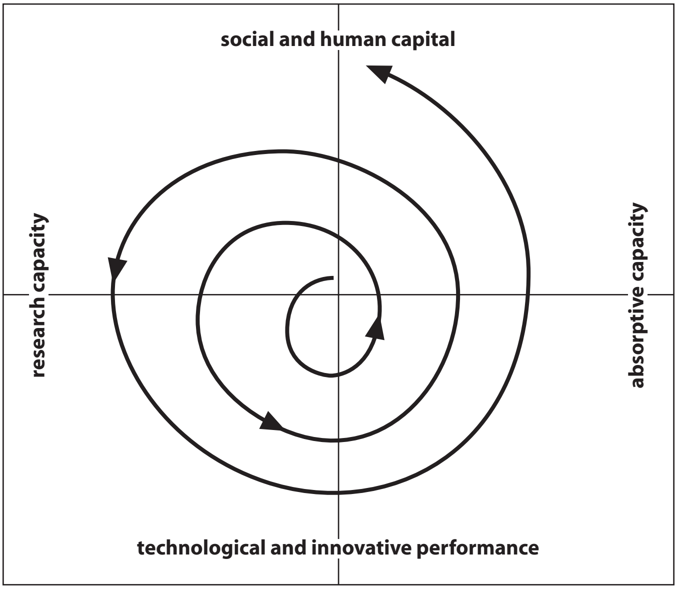
regional clustering of industrial activities based on the close interactions between suppliers and users, involving learning networks of various sorts between firms and between public and private players, represents a more flexible and dynamic organizational setup than the confinement of such learning activities within the contours of individual firms. Regional or local learning networks can allow for much more intensive information flows, mutual learning, and economies of scale among firms, private and public knowledge institutions, and education establishments. Some innovation management authors (Chesbrough 2003) like to refer here to the notion of "open innovation." The technological and innovative performance of firms is what can be most directly measured to approximate the degree of success of such clustering.

In a well-known study, Saxenian (1994) compares the effect of Silicon Valley and Route 128 in the United States. She cites Silicon Valley in California, where a group of entrepreneurs, helped by research efforts in local universities, contributed to development of a world center of advanced technology. She ascribed the success to the horizontal networks of informal and formal cooperation that arose among new firms in the area. By contrast, in the Route 128 corridor outside Boston, lack of interfirm social capital led to a more traditional form of corporate hierarchy, secrecy, self-sufficiency, and territoriality. The comparison shows that the innovativeness and technological performance of firms strongly depends on close interaction among them.

In addition to human capital, research, and the related phenomenon of local networks (particularly interfirm networking), the fourth and last factor essential to any innovation system approach is the *absorptive capacity* of firms, clients, and consumers in a particular region or country. The ability of companies to learn will, of course, in the first instance depend on their internal capabilities, which are represented by the number and level of scientifically and technologically qualified staff members. Firms must do enough R&D to be economically dynamic and to have the absorptive capacity to conduct a professional dialogue with the public research sector and other external sources of knowledge. At the same time, consumers, clients, and citizens might be very open to new designs, products, and even ideas, thereby enabling rapid diffusion of new products created by R&D in knowledge-intensive sectors, or might be very conservative, resistant to change, and suspicious of novelty. The absorptive capacity among countries, regions, or even suburbs varies dramatically.

Schematically, figure 2.1 illustrates the growth dynamics associated with an ideal national innovation system: the four key nodes proposed

Figure 2.1. An Ideal Virtuous Innovation Growth Circle



Source: Author's calculations.

above can be represented in a simple taxonomic way, opposing the relative importance given in science, technology, and innovation policy to supply versus demand on the one hand and users versus creators on the other. Supply will generally be dominated by public resources, and demand by private resources. The focus on users will be generally characterized by broad, economywide features, reflecting the effect of the diffusion of technologies; the focus on creators will be generally more specific. The four key nodes can be represented as mutually reinforcing elements of an interlinked circle with a positive overall effect on competitiveness and sustainable growth. From this perspective, I would argue that the most interesting and efficient set of science, technology, and innovation policy initiatives can be found in the interactions and interlinks among those four factors, and not just in UILs.

Using a combination of a variety of indicators for each of the four concepts discussed, researchers attempted to provide some empirical evidence about the workings of the respective national systems of innovation for the various EU countries. The study provided some broad evidence on the possible ways in which some of these key concepts interact in each of the 15 EU member countries prior to May 1, 2004.[4] The indicators were as follows:

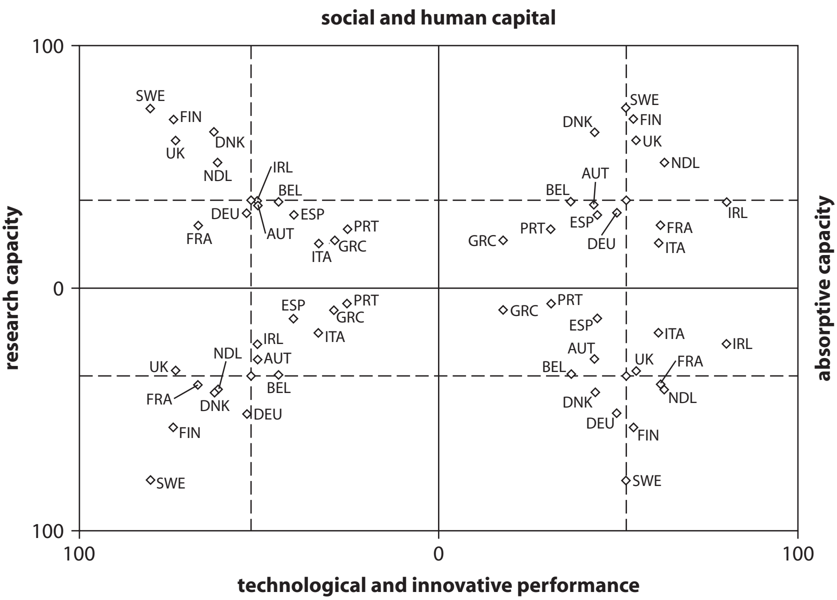
- *Social and human capital.* The concept of social and human capital, as previously discussed, is most closely related to measures of levels of education in a country and their maintenance. The human capital proxy used below is based on an average of three indicators: a human capital investment indicator reflecting the educational expenditures in a country (percentage of GDP spent on education), an output-based education performance indicator (percentage of working population with third-level degrees), and an informal training indicator (participation in lifelong learning).
- *Research capacity.* The long-term strength of the research system of a country is approximated here by its capacity to deliver highly qualified researchers (scientists and engineering graduates as a percentage of working population); the amount of public resources it is prepared to invest in R&D (government expenditure on R&D and higher education expenditure on R&D as a percentage of GDP) and the performance of its national research system (number of publications per million population).
- *Technological and innovativeness performance.* Technological performance is reflected in the more traditional research and technological development indicators, such as business-performed R&D (business expenditure on R&D as a percentage of GDP) and number of patents obtained (triad patents per capita). An innovation indicator (innovation expenditures as a percentage of total sales) provides additional information on firms' innovation efforts generally not captured in formal R&D investments or numbers of patents.
- *Absorptive capacity.* The concept of absorptive capacity is reflected in the successful diffusion of new technologies throughout the economy as measured by (a) a firm's capacity to renew its product range and adjust to technological change, based on the weighted average of sales of new-to-market products; (b) labor productivity, a more process-oriented measure of technological improvements; and (c) relative trade performance in high-tech goods, a competitiveness indicator.

[4] This activity was part of an EU research project initiated within the framework of the ETAN (European Technology Assessment Network) benchmarking project (Soete and others 2002). A more sophisticated and dynamic analysis can be found in Garcia (2006).

These four combined measures closely approximate the four concepts previously discussed and identified with Abramovitz (1986), for example. The proposed indicators are presented as *relative* indices, with the EU average equal to 100. In the figures 2.2 and 2.3, the various indicators are compared in their various combinations for each of 14 EU countries.

Figure 2.2 presents a simple illustration of an interlinked systemic view of the various EU member countries' national system of innovation, with the best performance always indicated by points positioned toward the outside of each of the four quadrants of the graph and poor performance reflected by the position of points near the center. The conclusion that emerges from figure 2.2 is that EU countries seem to have the supply side of their national systems of innovation well under control with, not surprisingly, substantial performance gaps between Europe's northern and southern member countries in human and social capital, public research efforts, and private technological and innovative performance. However, quite strikingly, member countries' absorptive capacity

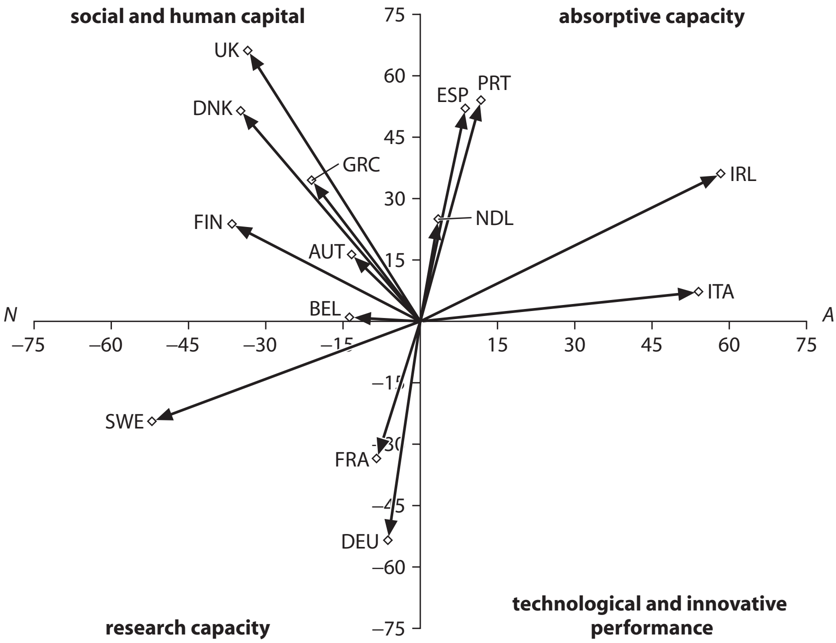
Figure 2.2. National UILs in EU Countries: A Bird's-Eye View



Source: Author's calculations.

Note: AUT = Austria, BEL = Belgium, DEU = Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, GRC = Greece, IRL = Ireland, ITA = Italy, NDL = Netherlands, PRT = Portugal, SWE = Sweden, UK = United Kingdom.

Figure 2.3. National UIL Strengths and Weaknesses



Source: Author's calculations.

Note: AUT = Austria, BEL = Belgium, DEU = Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, GRC = Greece, IRL = Ireland, ITA = Italy, NDL = Netherlands, PRT = Portugal, SWE = Sweden, UK = United Kingdom.

appears not to "fit the bill"; it has little relationship either with technological and innovative performance or with social and human capital. Hence, Abramovitz's observation of two decades ago appears as valid as ever (Abramovitz 1986).

In figure 2.3, the analysis is pushed a step further. By simply looking at each country's position in each of the quadrants of figure 2.2 relative to its position in the other quadrant, one can calculate the relative bias in each country's national innovation system. Looking at some of the most extreme positions in each of the quadrants, one may note four interesting features:

- First, the United Kingdom, in particular, but also Denmark, appears to be characterized by a national system of innovation heavily biased toward the higher education–basic research interrelationship. The intrinsic weakness of those countries' national innovation system resides in the technological innovation–absorptive capacity links, which appear insufficiently strong to compensate for the heavy focus on higher education–basic research.

- Second, Sweden's national system of innovation appears to be characterized by a strong bias in the research–technological performance relationship. In a much less extreme fashion, Germany also appears to be characterized by such a bias—nearer, however, to the technological performance end of the quadrant.
- Third, Ireland and Italy have a national system of innovation strongly biased toward absorptive capacity and weak on the research side; Portugal and Spain have their national system of innovation also biased in the same quadrant but much more toward the social and human capital end—the higher-education system. Those countries are weak where Sweden, in the case of Ireland and Italy, and Germany, in the case of Portugal and Spain, are strong.
- Finally, and most noticeable of all, no EU countries are located in the technological and innovative performance quadrant, pointing to a general European weakness in that area. When the data of Japan are added to the figure, Japan appears in this quadrant: a national system of innovation heavily biased toward the diffusion of technological and innovative performance.

Ideally, one would like to expand the analysis in figure 2.3 in a more dynamic fashion, rather than just comparing countries in a purely static way. Current research at United Nations University–MERIT (Maastricht Economic and Social Research and Training Centre on Innovation and Technology) by Abraham Garcia (2006) is elaborating further on a more dynamic approach to such links.

A Small, Highly Developed, Postindustrial Economy: The Dutch Case

Industrial R&D, as used and presented in figures 2.1 and 2.2, is of course heavily biased in favor of industrial production. Service sectors or other sectors not involved in research are likely to be underrepresented. Central in the research policy debate is the extent to which the commercial benefits of knowledge investments can be appropriated and by whom: the firm within the sector that made the R&D efforts or a firm upstream or downstream, or the final consumer, because imitation is taking place so quickly that none of the new product rents could be appropriated by the innovator. Sectors and activities with little registered R&D effort may well be highly innovative. Some of the most competitive Dutch industries, such as the offshore and dredge industry, the food-processing industry, and the finance or insurance industry, carry out little if any R&D. According to Organisation for Economic Co-operation and Development classifications, those industries typically involve medium to low technology. The knowledge bases appropriate for them, however, display great technical depth and variety. The list of institutions providing support and development of these bases is long and diverse.

The same argument holds at the international level. Again the central question will be whether the commercial benefits of knowledge investments can be appropriated domestically or are leaking to other countries. Most of the catching-up growth literature reviewed previously emphasizes the advantages to lagging countries, which benefit from the import of technology and knowledge, formally and particularly informally. In the current, increasingly global world economy, growing R&D investment is hence unlikely to benefit only the domestic economy. This hypothesis holds all the more for a small economy such as the Netherlands. Thus, as highlighted by Meister and Verspagen (2004), achieving the European so-called 3 percent (R&D/GDP) Barcelona target is not really going to reduce Europe's income gap with the United States, because the benefits of the increased R&D efforts accrue not only to Europe but also to the United States and the rest of the world. In a similar exercise, but limited to the R&D activities of U.K. firms in the United States, Griffith, Harrison, and Van Reenen (2004) found that such R&D activities contributed significantly to U.K. productivity growth: a shift of 10 percent of a U.K. firm's research activities to the United States from the United Kingdom would actually increase the firms' productivity by 3 percent.

But even acknowledging the increased importance of such international trends, more can be said about the particular Dutch case that might be of particular relevance to the issue of UILs. Elsewhere, I have referred to this problem as a *Dutch knowledge disease*. The term tries to explain the gradual decline in the trends in industrial R&D investments over the past 40 years in the Netherlands from its position as a technological leader in the late 1960s to a technological follower today in the area of private knowledge investments. Two underlying phenomena appear to be characteristic of this particular sort of disease.

First and foremost, as in the case of the Dutch disease,[5] a gradual crowding out occurs of essential elements of knowledge production and investment. As argued, or at least assumed, above, knowledge production is typically characterized by joint production aspects: strong complementarities between the knowledge investments of private and public parties based on the existence of close links. In the case of the Netherlands, this process led to strong R&D investments by the large Dutch multinational firms in the local economy. Such investments were often in line with Dutch public R&D investments. In the late 1960s, the Dutch economy actually witnessed the highest concentration of civilian (nonmilitary) R&D activities in the world. Technical high schools and universities were closely integrated in this privately led knowledge investment growth path. Until the 1980s, the five largest Dutch industrial companies represented more than two-thirds of all Dutch business-funded R&D investments. Not surprisingly, these firms witnessed an overconcentration of R&D investments in the Netherlands, certainly when compared to their international production activities. Along with the further internationalization (and Europeanization in preparation of the 1992 European single market) of production, R&D investments also became subject to internationalization. Initially, this change was limited to R&D activities strongly linked to the maintenance and adjustment of production processes and product technology to foreign market conditions.

In short, a wholly natural trend toward the international crowding out of Dutch private R&D took place. As a result, many of the close domestic connections between private and local public research institutions became weaker. This process is not yet finished and is likely to continue, given the still wide disparities in the concentration of domestic R&D versus international sales. (In the case of Philips, of a worldwide total of some €2.8 billion of annual R&D investments, approximately €1 billion is being spent in the Netherlands, which represents one-fourth of total private R&D investments in the Netherlands.)

This international crowding-out process was also accompanied by a process of R&D *content* crowding out, with a severe reduction in the amount of fundamental research being carried out by private firms. This

[5] This "disease" is also referred to as the "curse" of natural resources. In the case of the Netherlands, it involved the discovery of natural gas in the 1960s. Later on, it was a term that was used to explain the deindustrialization process of the United Kingdom following the exports of North Sea oil. The Dutch disease phenomenon is now typical for countries such as the Russian Federation, where the export dominance of natural resources undermines the competitiveness of other manufacturing sectors.

process took place in most large firms in the 1980s and found its most explicit expression in the reorganization of R&D activities, from autonomous laboratories directly under the responsibility of the board of directors to more decentralized R&D activities integrated into and becoming fully part of business units. Again, given the important concentration of such firms in the Netherlands, the Dutch R&D system was much more affected by this second process of crowding out than R&D systems of other countries in Europe. Today only Philips can be said to have kept fundamental research activities located in the Netherlands in its NatLab research facilities on the High-Tech Campus in Eindhoven.[6]

Awareness of this process led to the setting up in the Netherlands of joint private-public technological top institutes (TTIs), aimed at maintaining long-term fundamental research activities in the Netherlands in areas of particular relevance to the Dutch economy. Although successful overall, the TTIs (four in total) were not in a position to counter the process of content crowding out.

In combination, these two features of crowding out have increasingly made questionable the local joint knowledge-production advantages of operating in the Netherlands. Dutch firms have started to make more effective use of the presence abroad of possibly relevant knowledge centers. Highly qualified electronic engineers are not just available in Eindhoven. This process is continuing. Not only production is internationalized. Firms will increasingly shop on the world market for knowledge and choose the best locations to perform their R&D activities. In doing so, they will not only hope to make their own, in-house R&D more efficient, but also look to the efficiency, quality, and dynamics of the external, local knowledge institutions, such as public R&D institutions and universities. Various surveys about the internationalization and possible relocation of Dutch R&D business activities point to the fact that this internationalization trend is far from over; it is likely to continue—not so much any more in the direction of the United States, but rather in the direction of China, India, and Eastern Europe.

Meanwhile, as a second phenomenon, public knowledge investments became increasingly subject, as in other countries, to national public scrutiny, performance assessment, and academic peer review. As a result, academic performance became the dominant incentive in public

[6] This process is reflected, for example, in the number of scientific papers published by authors from private firms. Today in Europe, only a few firms, Philips being one of them, have scientific papers published.

research institutes: applied, more immediately relevant research became second rate. In the Netherlands, with its dominant large public research institutes, such as the Netherlands Organization for Applied Scientific Research, this change meant that applied research was effectively crowded out of the university environment. Today, national performance of scientific research in the Netherlands—measured, for example, by number of publications per researcher or per million euros spent on public R&D—is not inferior to that of the United States. Throughout the years, with the increasing dominance of English as the language of scientific communication, the growth in the total production of internationally read and reviewed scientific articles in the Netherlands has actually been much higher than in the United States.

Characteristic of public research is its national embeddedness. From this perspective, the policy toward increasing competition between Dutch universities and public research centers, as was the case with the formation of so-called research schools, produced important quality impulses in Dutch public research but led *not* to specialization of research but rather to further research duplication. Practically every university jumped on the same new, promising research areas (life sciences, nanotechnology, information technology, new materials), competing nationally and worldwide to recruit leading Dutch and foreign researchers. This process resulted in a multitude of different, relatively small research groups, each of them seeking additional funding and networks through European funding programs.

Such opposing trends—private research dominated by internationalization and specialization, on the one hand, and public research dominated by nationalization and duplication, on the other hand—led ultimately to increasingly weak links between public and private R&D. Michael Porter (2001) described this process, in his Dutch "Innovation Lecture 2001," as unsustainable. The initiative of the TTIs in the mid-1990s, as already mentioned, aimed at steering public research, on the basis of financial matching from private and public resources, toward the long-term research needs of firms located in the Netherlands. In other words, policy makers, too, especially those at the Ministry of Economic Affairs, have been aware for over a decade now of the increasing duality between publicly oriented and privately driven research.

In sum, Dutch national policy aimed at strengthening the links between universities and industry has been trying to reactivate the formal and informal connections between the public and private knowledge investment parts of the Dutch national system of innovation. Given the international specialization pattern already developed in the Netherlands in the privately driven research sector, one might argue that the private sector should take the lead in strengthening such links. Practically, building new formal bridges could take the form of a new round of TTIs in fields essential to the Dutch economy. Topics for such a new round of TTIs should obviously include not only private sector research interests but also public research interests (security, mobility, sustainability, aging). Alongside such a demand-led set of reactivating link policies, one should also focus on other forms of joint knowledge-production policies: for example, policies providing stronger and more-effective incentives for scientific entrepreneurs, policies aimed at increasing mobility between public and private research labs, and policies opening private research labs to public (and other private) research interests. In short, national policies should focus on pulling together and coordinating the various components of joint knowledge production.

References

Abramovitz, Moses. 1986. "Catching Up, Forging Ahead, and Falling Behind." *Journal of Economic History* 46 (2): 385–406.

Aghion, Philippe, and Peter Howitt. 2006. "Joseph Schumpeter Lecture; Appropriate Growth Policy: A Unifying Framework." *Journal of the European Economic Association* 4 (2–3): 269–314.

Chesbrough, Henry William. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business Review Press.

Fagerberg, Jan. 2002. *Technology, Growth, and Competitiveness: Selected Essays*. Cheltenham, U.K.: Edward Elgar.

Garcia, Abraham. 2006. "National Systems of Innovation and the Role of Demand: A Cross Country Comparison Based on Composite Indicators." UNU-MERIT Working Paper, forthcoming, United Nations University-MERIT, Maastricht.

Gerschenkron, Alexander. 1962. *Economic Backwardness in Historical Perspective*. Cambridge, MA: Belknap Press.

Griffith, Rachel, Rupert Harrison, and John Van Reenen. 2004. "How Special Is the Special Relationship? Using the Impact of U.S. R&D Spillovers on U.K. Firms as a Test of Technology Sourcing." IFS Working Paper W04/32, Institute of Fiscal Studies, London.

Meister, B. Christoph, and Bart Verspagen. 2004. "European Productivity Gaps: Is R&D the Solution?" ECIS Working Paper 2004–03, Eindhoven Centre for Innovation Studies, Eindhoven University of Technology, Eindhoven, Netherlands.

Perez, Carlota, and Luc Soete. 1988. "Catching Up in Technology: Entry Barriers and Windows of Opportunity." In *Technical Change and Economic Theory*, ed. Giovanni Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg, and Luc Soete, 458–79. London: Pinter.

Porter, Michael. 2001. "Innovation and Competitiveness: Findings on the Netherlands." Innovation Lecture 2001 presented to the Netherlands Ministry of Economic Affairs, The Hague, December 3.

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

Soete, Luc. 1981. "Technological Dependency: A Critical View." In *Dependency Theory: A Critical Reassessment*, ed. Dudley Seers, 191–206. London: Pinter.

———. 1985. "International Diffusion of Technology, Industrial Development, and Technological Leapfrogging." *World Development* 13 (3): 409–22.

Soete, Luc, Dermot O'Doherty, Erik Arnold, Ahmed Bounfour, Jan Fagerberg, Ugo Farinelli, Ken Guy, Dimitris Kyriakou, Bengt-Åke Lundvall, Ian Miles, Pascal Petit, Michèle Sanglier, and Gerd Schienstock. 2002. *Benchmarking National Research Policies: The Impact of RTD on Competitiveness and Employment (IRCE)*. Strata-ETAN Expert Working Group, European Commission DG Research, Brussels.

CHAPTER 3

University-Industry Knowledge Transfer in Switzerland

Dominique Foray

Many economic opportunities exist for exploiting potential transfers from academic research to industry, generating a range of complementary externalities between the two systems (David 1998). One such source of externalities is the intellectual support that fundamental scientific knowledge provides to applied researchers, whether in the public or the private sector. A second and no less important source is the link between the profitability of corporate research and development (R&D) and the quality of human capital, and as it turns out, universities have been the best place to train young scientists and engineers. Finally, the effective transfer of knowledge and technology from university research laboratories to corporate labs attributable to the circulation of academic

In this paper, I draw heavily on some of the research projects that the chair of economics and management of innovation at the École Polytechnique Fédérale de Lausanne is developing on university-industry knowledge transfer in Switzerland. Contributions by Stephane Lhuillery and Christian Zellner are gratefully acknowledged. I am also grateful to Intan Hamdan for editorial assistance.

researchers is an externality that feeds into the viability of the overall symbiotic system of academic research and industry. The main effects of those complementarities are to raise the expected rates of return and to reduce the risk of investing in applied R&D. A central policy concern is, therefore, to ensure that the complementarities are properly managed and that they serve to maintain the profitability of applied R&D investments for firms as they have for the past half-century.

This policy concern becomes even more nuanced as countries progressively shift toward knowledge-based economies.[1] It is critical that the supply of new basic knowledge and highly skilled people enable the country to respond positively to the increasing demand for those resources that arises as a consequence of the expansion of the knowledge sector. Efficient knowledge-transfer mechanisms are therefore crucial to properly feed and sustain the growth of these knowledge- and innovation-based activities.

Direct transfers of knowledge between universities' science communities and the proprietary R&D organizations of the private business sector have been largely accepted as problematic to institutionalize. The coexistence of two reward systems within any single organization makes the behaviors of the participants difficult to anticipate and tends to undermine the formation of coherent cultural norms that promote cooperation among team members (David, Foray, and Steinmueller 1999). The difficulties of technology transfer are not raised in the first instance by wrong or ill-adapted institutional frameworks, legal systems, or cultural norms; rather the difficulties are inherently associated with the process itself, which is a problem shared by all countries. In no country is technology transfer a simple task, because the problem has the structure of a trade-off between two good things: applicability of academic knowledge useful to the economy and maintenance of the fundamental missions of long-term research and training.

Numerous issues are involved in the process of transferability and operation of new knowledge as produced in academic institutions. In this chapter, I restrict this discussion to a few points that I think are relevant for national policies, using references to relevant experiences of Switzerland whenever possible.

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[1] *Knowledge economy* is defined as the sector of production and service based on knowledge-intensive activities, activities that are essentially oriented toward innovation and the continuous supply of "new to the world" goods and services.

Three Levels of Policy Objectives

Three distinct levels of policy objectives are connected to the relationships between university and industry research. The first one involves *seeking optimization complementarities* between university and industry in a broad perspective through identification of the proper framework conditions as well as generation and development of favorable structural characteristics of the national system of innovations. Here the neutrality concept forms the basic premise of such objectives so that the usual problems of selection of winners, government failures, competitiveness distortions, and early lock-in are mitigated. The minimization of discrimination in the public funding allocation process among technologies or sectors thus ensures that resources allocated respond to market signals rather than bureaucratic decisions. However, technology policy could opt for nonneutral allocation policies along at least two dimensions: according to fields and according to type (by size) of firms. These two dimensions correspond to the two other levels of the policy objectives: *targeting small and medium enterprises (SMEs)* to help them cooperate with universities and *using university-industry relations to lever the whole system up to new specializations* of high productivity potential for the future.

Seeking Optimization Complementarities: Framework Conditions and Structural Characteristics

Several issues arise regarding the first level of policy objectives.

Developing Engineering and Technology An important issue is institutionalization and development of engineering. A pivotal element in the chain of events occurring between the two spheres (abstract research and concrete applications) is a powerful engineering discipline in the field under consideration (computer, chemical, aeronautical, electrical). Engineering sciences support the gradual transformation of knowledge from ideas to operational concepts and the passage of knowledge from one codified form (perfectly adapted at some level of abstraction) to another codified form (that is adapted to application). The tensions described above are, therefore, expected to be weaker than in the context of pure fundamental research activities. According to Nelson and Rosenberg (1994), the early recognition of engineering sciences by U.S. universities and their high valuation as academic fields are important factors in explaining the relative success of U.S. universities in transferring knowledge to industry. And as Rosenberg (2005) showed, these factors lay the foundation for the profitability of scientific research by creating an impetus toward transforming basic knowledge and creating learning programs to be systematically used by engineers to improve products and processes and by establishing a new engineering discipline.[2]

Engineering schools should, therefore, logically be more "permeable" than basic science and other schools to the industry (Lécuyer 1998), while specially designed institutions that have research missions distinctive from that of either traditional academic science or profit-oriented R&D laboratories may be more effective for facilitating technological transfers.

The allocation of resources to different kinds of specialized institutions that conduct specific scientific research activities is a recurring policy problem. The answer is not obvious. Although the rationale for public support of research—as a general principle—is still valid, viewing public science policy as a tool to influence the allocation of resources among research fields is a less obvious rationale. Recognizing that incentives play a significant role in the decision-making process on university campuses, just as they do in every other part of life, is crucial. Giving universities the autonomy and freedom to build their research portfolio according to their own perceptions of the kinds of opportunities offered by their local (or more global) environment is probably a good idea. As a general principle, university-level managers appear better positioned than state authorities to generate virtuous dynamics of resource allocation among academic fields. Nevertheless, a state-pushed program should not be precluded in the cases in which the discipline does not exist. Considerable evidence has demonstrated that the areas of greatest returns from scientific investigation lie at the interstices of established fields. And given that the problem of creating, developing, and institutionalizing a new field at the interstices of strong existing disciplines is characterized by severe research market failures (mainly attributable, in this case, to increasing returns phenomena), some government intervention may be necessary, particularly in countries where engineering sciences are weak.

Attracting Anchor Tenants The *anchor tenant hypothesis* assumes that R&D capacities above a certain size are powerful in generating externali-

[2] The notion of *use-inspired basic research*, attributable to Donald Stoke and popularized among economists by Nelson and Romer (1996), provides another conceptual category to describe the same idea that dedicated fields, projects, or disciplines are needed to support knowledge transfer.

ties in the form of thickening markets for innovation and technologies on both supply and demand sides so that local university research is more likely to be absorbed by and to stimulate local industrial R&D (Agrawal and Cockburn 2002). An anchor tenant (AT) exhibits two important features: strength in R&D in general and strength in the fields of expertise of the local universities. Thus, a global company can be an AT in any given region for any given field and will not be an AT in another region for the same field. Agrawal and Cockburn gave two reasons for thinking that the presence of an AT will enhance the regional innovation system and will help the relations between local universities and the industry (including SMEs).

- ATs may be directly involved in commercializing university inventions.
- ATs may also indirectly stimulate innovative activity by enhancing both the supply and demand sides of the market for new technologies. ATs thicken markets for scientific labor and for innovation services (intellectual property legal counsel, technology marketing, human resources services) and enhance social networks with suppliers, buyers, and partners. They can also play a dynamic role on the demand side by absorbing industrial R&D output from local smaller firms.

Agrawal and Cockburn have shown empirically that AT firms are important to the institutional structure of local innovation systems, because they improve the whole set of links between local universities and local firms.

The issue of creating and increasing locational advantages to attract a large number of ATs determines policy options of wider relevance than improving university-industry relations. The whole menu of policy orientations involves enhancing knowledge infrastructure to create an adequate supply of human capital, ideas, and academic collaborations. R&D managers, when undertaking location decisions, must be able to anticipate a positive supply response of the domestic knowledge infrastructure to their demand for scientists, ideas, and academic collaborations. Furthermore, this policy menu involves improving innovation capacities, including selecting (and moving toward) the "right" science and technology (S&T) specializations. The quality, dimension, and specialization of the knowledge base are key factors driving location decisions.[3]

[3] Another issue is ensuring the coherence of the knowledge base: science and public research specialization must be in harmony with the competitive strengths of the industry.

Increasing Human Mobility The mobility of people across institutional boundaries is clearly a factor mitigating many of the tensions that arise in settings where the conventions, culture, and norms of one world (private industry) come up against the conventions of another (Hall 2004). In this context, among the most helpful of mobile human resources are new PhDs entering their first job. Their placement with industry provides a means by which knowledge is transferred from the university and by which networks are built and reinforced, thus providing a major mechanism by which universities and firms interface (Sumell, Stephan, and Adams 2005). Sumell and colleagues argued that having graduates work for neighboring firms strengthens the interface between the university and firms at the local and regional level. Thus, the mobility of the highly educated obviously affects the extent to which the local economy absorbs knowledge created in universities. The policy implication of influencing the location decision of new PhDs working in industry, so that they stay, is clear. Development of locational advantages should be addressed from this perspective. The famous Midwest syndrome in the United States is an illustrative case of policy failure on this issue: states in the Midwest are net exporters of PhDs, hiring a third fewer than they train (Sumell, Stephan, and Adams 2005).

Helping Cluster Formation Spatial cluster of activities is at least partially explained by the advantage of proximity and the necessity of collocation in the process of knowledge creation and transfer. Geography's significance in explaining the importance of spillovers is indisputable. A case exists, therefore, for policy aiming at the creation of proper conditions for the development of spatial clusters, involving both industry and universities. However, proximity in itself may be not enough. The way in which professional communities use it to combine their tangible and intangible assets is what counts. Depending on the dynamics created, proximity remains a purely geographic phenomenon or becomes an effective organizational structure for knowledge creation and transfer. Thus, Silicon Valley is not only a territory; it is above all a set of collaborative practices that blur the boundaries between various types of institutions (Saxenian 2001).

Disseminating an Intellectual Property and Knowledge Management Culture in Universities Knowledge management involves a set of tools and organizational practices that have not yet really been used in universities to support and promote knowledge transfer. Knowledge management policy in this case should involve the creation of incentives for the disclosure problem, the development of interfaces and specific institutions to support transfer, and the development of indicators to evaluate intellectual capital. Knowledge management is broader than intellectual property (IP) management. However, an effective IP policy is part of the agenda. Postinvention processes may require codevelopment—that is, the active involvement of the two sides in modification and further development. This need can make the problem of negotiating the attribution of rights especially difficult to solve. Universities must impose a clear definition of the scope of knowledge that is transferred, as well as of what is "generic" and what has been created before the involvement of the licensee. Those issues are key in maintaining the freedom of operation for future research. However, codevelopment makes this attribution of rights very complex and uncertain.

Does any policy rationale deal with these issues? Instead of financial incentives, information provision should be the main policy goal here. As has been well known for some time,

> awareness is of course the start. After all if people are unaware of office automation and its benefits, they can't be expected to exploit them. The Department's first aim therefore is to encourage the sort of evangelism which not only sells the improvements in productivity and efficiency which office automation trails behind it, but also shows firms how to go about achieving them (David and Stoneman 1985, quoting U.K. Department of Industry [undated]).[4]

Targeting SMEs to Overcome Absorptive Capacity Problems

One possible departure from the neutrality principle is the varying support to firms of different sizes. The rationale for making such distinctions is that large companies are usually considered, in the literature, an efficient solution to most of the problems raised by the allocation of resources in R&D,[5] including those connected to building relations with university research. Given their size, SMEs have logically had more difficulties in optimizing complementarities with university research.

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[4] The reader is invited to read "office automation" with "knowledge management" in mind.

[5] These problems include the inability to diversify risk where capital markets are incomplete or imperfect, the inability to minimize transaction costs when complete contracts cannot be written, and the inability to capture spillovers or other externalities. A strong presumption exists that vertical integration is the first, best solution to most of these economic problems.

They have difficulties in articulating their research and collaboration needs, and they usually cannot afford to divert human resources to organize and manage the collaboration. Divergences and tensions are difficult to minimize because of the lack of "translators" (such as employees in large companies who have academic research background or postdocs who are specifically hired to facilitate such relations). Moreover, SMEs are less visible from the great academic laboratories, and the latter have no strong incentives to invest in building relations with the former. As a consequence, fewer links exist between SMEs and the academic research system in many countries.

The policy goal should be to support and promote, with specific instruments, the relationships between universities and SMEs.

Using University-Industry Relations as Leverage for Strategic Capacities

Departing from neutrality in regard to technological fields has always been tricky because it entails the risk of market and competition distortions. Thus, policy makers should avoid it except in cases where glaring market failures need to be remedied. A case in point deals with the difficulty—because of coordination failures—of moving a whole system to new areas of great productivity potential for the future. In this case, the move toward a new target and shifting of resources away from areas of lower productivity into areas of greater productivity can take place only when the country exhibits effective strategic capacities—that is, the capacity of governments to create satisfactory incentives and motivations to move the whole system. Such a strategy capacity is based on a huge commitment of government resources to a new field through investments in building knowledge infrastructure, government-sponsored research, and public procurement. The success of this policy is strongly conditional on the positive responses of the private sector to those incentives.

The recent history of technology policy in countries belonging to the Organisation for Economic Co-operation and Development (OECD) shows that such strategic capacity (involving nonneutral public interventions) has been a key factor, notably in building U.S. leadership in the high-technology economy.[6] For example, collaborations between re-

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[6] The ingredients of the U.S. strategic capacity are known. It involves a diversity of public agencies, all working on specific but overlapping agendas; a key role for the Department of Defense showed both in the history of the Internet revolution and, recently, in information security R&D programs launched after September 11, 2001. In both cases, the effect of government-sponsored research was great in building knowledge infrastructure in particular areas, in generating spillovers to the benefit of industry (including SMEs), in creating incentives for business R&D to respond positively to this policy, and in initiating market development through public procurements.

searchers and product developers have had salutary effects on improving computing research, helping to ensure the relevance of academic research, and helping industry to take advantage of new academic research. Such collaborations allowed government program managers to better leverage their resources by attracting industry contributions (CSTB 1999; Mowery and Simcoe 2002).

The success of such policies has been strongly contingent on careful policy design (including attention to competition policy issues) to avoid or reduce the potential problems previously identified (such as picking winners) (see Mowery and Simcoe 2002).

Involving and using university-industry relationships as leverage for strategic capacities can thus be considered an important policy objective. However, doing so would involve the need to carefully identify priorities (fields, topics) and the commitment to promote intensive university-industry research collaborations and investment in the building of hybrid research communities.[7]

National Case: Switzerland

With this background in mind, we turn now to the case study of university-industry knowledge transfer in Switzerland.

Evidence

The most recent survey undertaken by the Swiss Institute for Business Cycle Research (Konjunkturforschungsstelle, or KOF) on university-industry research relations provides interesting figures about how Swiss firms evaluate the importance of five generic transfer mechanisms (Arvanitis, Hollenstein, and Marmet 2006) (see table 3.1). Informal channels and a wide spectrum of education-related activities appear to be the most important forms, as evaluated by private companies. Surprising is the relatively low score of research cooperation, research contracts, and research consortium as a knowledge-transfer channel.

[7] The issue is more complicated than simply selecting the most exciting fields and allocating resources there. The problem is not trivial: technology foresight and forecasting approaches tend to produce the same priority ranking regardless of the context of the clients for whom they are prepared. In some countries, public policy has perhaps overemphasized new science-based, leading-edge industry in an unimaginative way, resulting in greater uniformity of their national knowledge bases and deterioration of their distinctiveness and originality. A possible consequence of this focus is that large companies suffer in global competition or act increasingly as a global knowledge network, allocating their innovative activities outside the home country. Policy makers must pay attention to this "particularization" process to find the key areas for focus.

Table 3.1. Main Transfer Mechanisms as Evaluated by the Industry

Knowledge- and technology-transfer activities	*Knowledge- and technology-transfer active firms reporting 4 or 5 on a 5-point Likert scale (%)*
Informal	56.6
Contacts	30.4
Conference	30.4
Publications	33.1
Technical infrastructure	11.9
Common lab	3.9
Use of university technical infrastructure	10.7
Education	52.3
Employment of graduates in R&D (plus contacts)	28.5
Students' participation in firm R&D	10.9
Joint diploma theses or joint PhDs	22.7
University researcher participation in firm	10.1
Enrollment in university training course	22.1
Research	17.8
Joint R&D projects	16.3
Long-term research contracts	5.0
Research consortium	4.1
Consulting	15.3

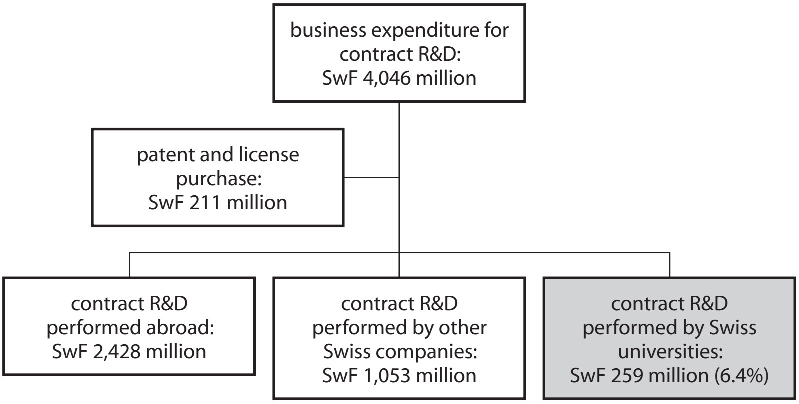
Source: Arvanitis, Hollenstein, and Marmet 2006.

Note: Based on 669 firms.

This finding is consistent with some results of the Swiss Federal Office of Statistics (Office Fédéral de la Statistique, or OFS) survey on private R&D expenditures (figure 3.1). In 2004, the business sector spent approximately SwF 4,046 million for contract R&D performed everywhere and in all sectors. Of this amount, SwF 2,428 million was spent for contract R&D performed abroad, SwF 1,053 million for contract R&D performed by other Swiss private companies, and only SwF 259 million for contract R&D performed in domestic academic research institutions (6.4 percent of the total of extramural expenditures). This last figure is worrisome. Although international comparisons are difficult, 6.4 percent can be presumed to be very low.[8]

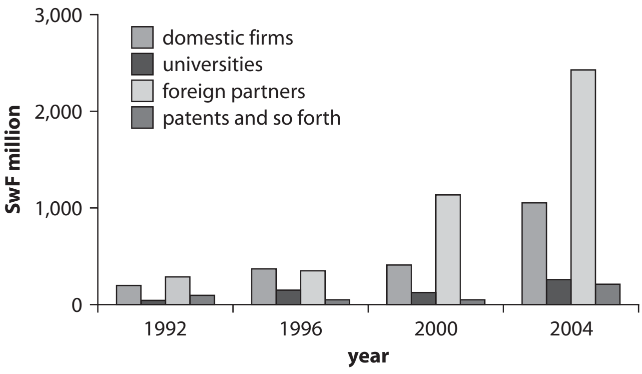
[8] In a personal communication with the author during the World Bank Paris conference, Mowery argued that the amount of contract R&D expenditures by U.S. private companies destined for U.S. universities is much higher than the Swiss figure.

Figure 3.1. R&D Contracts by Destination and Receiving Institutions, 2004



Source: OFS 2005.

Figure 3.2. Historical Evolution of Extramural R&D Expenditures



Source: Arvanitis, Hollenstein, and Marmet 2006.

Put in a historical perspective (figure 3.2), we see that R&D contracting out increased at an extraordinary rate. The amount destined for foreign partners increased at a higher rate than that received by domestic partners. The amount destined for Swiss universities also increased (by a factor of five) but remains lower than the amount received by the business sector.

Surprise?

This fact is surprising given that many structural characteristics of the system strongly favor complementarities between university and industry research:

- Swiss knowledge infrastructure (scientific research, S&T human resources) is considered excellent, ranking very close to the top in many fields. For example, in terms of scientific publication intensity and the relative prominence of cited scientific literature, Switzerland is ranked among the top two worldwide (OECD 2005b). Switzerland also has a very strong basic research capacity, which is partly funded by the private sector.
- The development of engineering and applied science is a case in point. The two institutes of technology (École Polytechnique Fédérale, or EPF, of Zürich and Lausanne) are rightly considered the jewels of the crown, having developed historically a strong academic research tradition in engineering sciences and applied sciences. They are very generously funded at the federal level and strongly committed to relations with industry. They exhibit most of the characteristics of the "permeable engineering school" described by Lécuyer (1998) à propos the Massachusetts Institute of Technology. Those factors hint at the positive response of the knowledge infrastructure to the growing demand of the business sector in terms of knowledge, highly skilled people, and collaboration with academic partners.
- On the demand side, the situation is again very good. An important characteristic is related to the size structure of Swiss industry and services: for a country of its size, Switzerland has an unusual number of large multinational companies. The list includes not only big banks and insurance companies but also a good number of global firms in high-tech sectors, such as Novartis, Roche, Nestlé, Rolex, Swatch, ABB, Sulzer, and Serono, which are able to develop global links working to the advantage of the originating location. These companies are likely to play the role of ATs, making the whole local system more innovative and more oriented toward cooperation with local universities.
- Finally, the innovativeness and absorptive capacities of Swiss SMEs are outstanding. SMEs in Switzerland are on average more innovative than those in any other OECD countries (in terms of patents, R&D intensity, and involvement in international cooperation). Clearly, the whole industry structure exhibits good characteristics.

- A virtuous combination exists, therefore, of ATs, innovative SMEs, excellent academic research, a high level of financial development, and a large proportion of foreigners in the positions of PhDs, postdocs, and S&T human resources population. This combination creates strong impetus toward the formation and development of high-tech clusters—as in Arc Lémanique, the Zürich region, northwest Switzerland (Basel), the Jura region, and the Berne region—involving the creation and entry of new high-tech firms with relatively little government intervention. The existence of clusters integrating scientific research, industries, and services and the banking system clearly plays a key factor in the development of university-industry relations.[9]

Any expert exposed to such an enthusiastic description would expect successful and flourishing research collaborations between university and industry. However, this result has not been achieved, and both good and not-so-good reasons exist for this outcome.

R&D Internationalization and the Size of the Domestic Knowledge Base as "Good Excuses"

One good reason is the level of internationalization of Swiss companies. Swiss companies have been increasing their R&D foreign direct investment significantly (see figure 3.3). The share of foreign R&D expenditures of Swiss-based firms reached 54 percent in 1996 and remained more or less unchanged until 2004, creating an impetus for the development of academic collaborations with foreign universities.[10] Moreover, the growth of research collaborations with foreign partners seems to be a parallel development. Even Swiss SMEs are heavily involved in such research collaborations: 17.3 percent of patent applications by Swiss SMEs are copatent applications involving foreign inventors, a percentage unbeaten elsewhere when surveying SMEs in other OECD countries. Because foreign R&D is a means of tapping into the worldwide pool of knowledge to complement the domestic knowledge base, R&D contract

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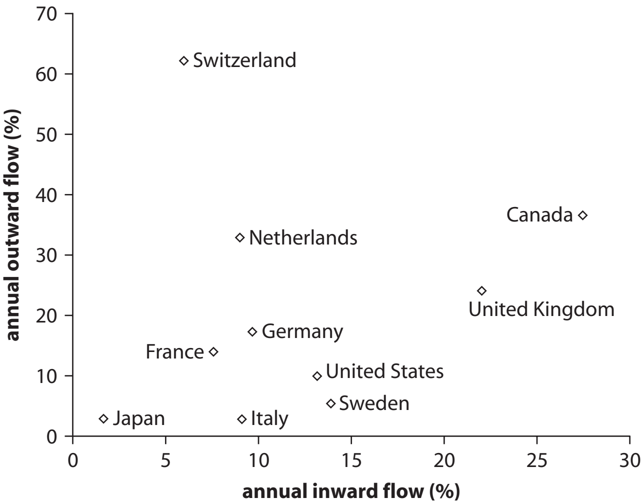
[9] Zellner (2005) presents a case study of the creation of high-tech start-ups at École Polytechnique Fédérale de Lausanne and analyzes the various factors that are likely to explain the relatively low growth performances of most of these companies.

[10] For example, Novartis moved R&D capacities to Cambridge, Massachusetts, some years ago and established more than 100 research collaborations with academic teams based in that area.

Figure 3.3. Multinational Enterprise R&D Inward (to the United States) and Outward (from the United States), 1999–2001



Source: Jaumotte and Pain 2005.

expenditures and R&D collaborations destined for foreign institutions are quite logically increasing at a high rate.

The size and specializations of the Swiss domestic knowledge base are another reason that research collaborations between universities and industry have failed to flourish. Switzerland is a small country, and its academic research institutions are unable to cover the whole range of fields and research topics that are likely to be of interest for industry. Therefore, a size effect explains part of the problem of the relatively low importance of research cooperation, research contracts, and research consortium as a knowledge-transfer channel. From a policy point of view, not much can be done, and the industry response of tapping into the global knowledge pool is certainly the right one.

Systemic Failures

Nevertheless, some failures in the system explain (partly) the relative lack of successful and flourishing university-industry research collaborations. These systemic failures require policy responses.

Low Participation in Tertiary Education A major drawback concerns the production of highly skilled human capital. Quite low participation in tertiary education results in a limited domestic supply of scientists and engineers.

This lack is compensated to some extent by large inflows of foreign students, scientists, and engineers. However, this situation deprives the domestic economy of a key element in the knowledge-transfer chain, which is the young scientist or engineer taking his or her first job. When the young scientist comes from abroad to be recruited by a Swiss-based company, the link between the firm and the local university is not established. Moreover, the very high proportion of foreign PhDs and postdocs makes it likely that a significant fraction of these students will leave the country after having completed their studies,[11] and this situation again is a major impediment to university-industry relations.

As a policy response, significant efforts have already been made by upgrading vocational education at the secondary school level and by creating universities of applied sciences that allow students to conclude vocational education at the university level. The authorities are currently preparing a reform of the whole system, which will improve the quality and efficiency of university education by reducing, for example, the time required to complete studies.

Problems at the Interfaces

Let us return for a moment to the KOF survey (Arvanitis, Hollenstein, and Marmet 2006). Firms were asked to evaluate the importance of different obstacles to knowledge-transfer activities, and firm deficiencies clearly appear as a problem (lack of interest in scientific projects; firm R&D questions not interesting for universities) (table 3.2). In addition, deficiencies of scientific institutions are perceived as an important obstacle, together with the costs, risks, and uncertainties of knowledge-transfer activities.

In sum, most important obstacles can be localized at the interface. Many firms think that their R&D questions are not interesting for universities, and many firms think that R&D orientations of universities are not interesting for firms. Clearly, firms with a focus on research activities do not seem to be seriously hampered by this category of impediments. However, some obstacles and impediments have clearly not been removed yet. How the government responds to this specific issue through policy choices will be interesting.

[11] The fact that foreigners cannot stay in the country for more than one month after having defended their thesis (a work permit issue) makes the problem worse. Switzerland is probably the only country that does not make its best effort to encourage foreign PhDs to stay!

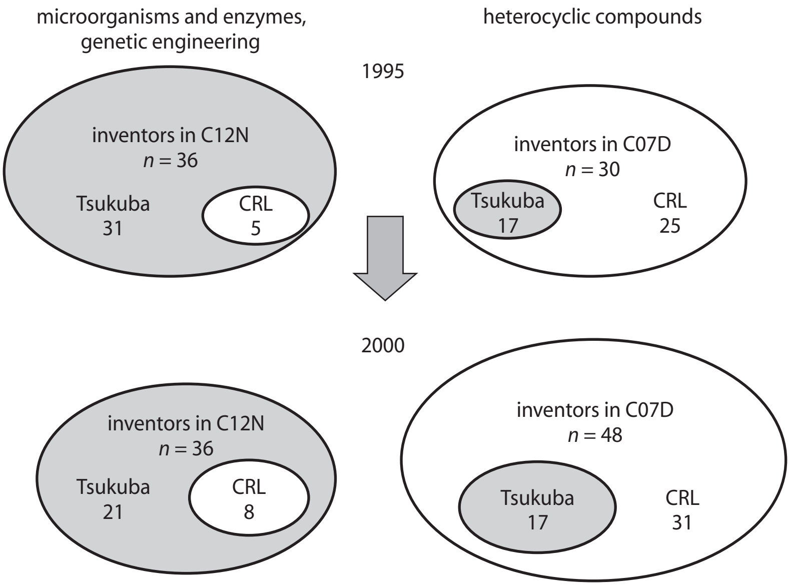
Table 3.2. Obstacles to Knowledge-Transfer Activities

Obstacles	*Firms active in knowledge transfer reporting a single obstacle as important (%)*
Lack of information	24.1
Difficulties finding contact persons	17.9
Firm deficiencies	49.2
Lack of interest in scientific projects	25.0
Firm's questions not interesting for universities	35.9
Deficiencies of universities	42.0
R&D orientations of universities not interesting	25.6
Possible R&D outcomes cannot be commercialized	25.3
Costs and risks	42.4
Lack of in-house financial resources	27.4
Lack of university financial resources to cooperate on an equal basis	12.3
Costly administrative procedures	15.0
Uncertainty about outcomes of cooperation	10.8
Institutional obstacles	24.5
Secrecy not guaranteed	10.3
Problems with intellectual property	6.4
Different understanding of priorities	10.1

Source: Arvanitis, Hollenstein, and Marmet 2006.

Problem with the Universities of Applied Sciences A hot political debate is now taking place to address the issue of rearticulating the role of the universities of applied sciences (UASs) vis-à-vis technological transfer and SMEs. UASs were created to increase the participation of students in tertiary education—the low participation is a historical feature that may create problems for the knowledge economy. UASs offer tertiary type B education and are clearly oriented toward applied research and relations with local industry. In practice, however, the results have not proven satisfactory. The EPFs, for instance, are more inclined toward technology-transfer activities than universities and universities of applied science (see figure 3.4). Because UASs do not deliver master's students and have no doctoral schools, they lack R&D personnel (PhDs, postdocs, researchers, professors) and are thus not equipped to respond positively to the needs and demands of their local environment, although such response is part of their mission.

Figure 3.4. Percentage of Firms with Technology-Transfer Activities by Partners in Suisse Romande, 2004



Source: Arvanitis, Hollenstein, and Marmet 2006.

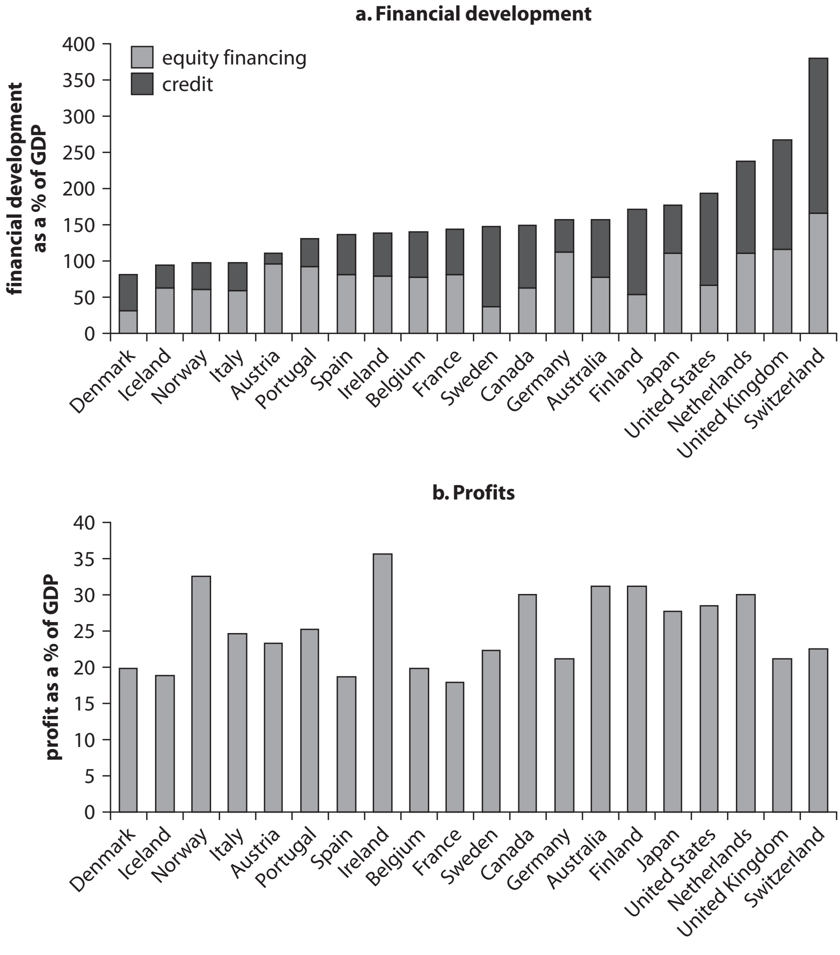
Note: EPFL = École Polytechnique Fédérale de Lausanne; UNIGE = University of Geneva; UNIL = University of Lausanne; UNINEU = University of Neuchâtel; UASNEU = University of Applied Science (School of Engineering, canton Neuchâtel); UASVAL = University of Applied Science (School of Valais). Five other UASs exist but have percentages lower than 2.3.

The Policy Response

Swiss innovation policy strongly focuses on promoting cooperation and network building between industries and universities. Switzerland has no tradition of direct policy interventions (like direct funding). Firms are subsidized only indirectly. This policy is partly related to the financial development of the country (ranked first), which means that firms usually have no problem funding their projects (even the most risky and uncertain of them) (figure 3.5), and partly related to the predominant laissez-faire ideology of most political parties. In a certain sense, this "no provision of direct financial support for business R&D" seems appropriate given the already very high level of business R&D and, hence, the risk of large deadweight losses.

Thus, the main policy mechanism deals with promoting technology transfer and research cooperation between universities and industry. The Commission for Technology and Innovation (CTI) finances R&D

Figure 3.5. Financial Development and Profits, 1996–2000



Source: Jaumotte and Pain 2005.

Note: Financial development is defined as the sum of credit and equity financing. *Credit* refers to private credit by deposit money banks. *Equity financing* refers to stock market capitalization.

for the business sector at Swiss public research institutions according to a public-private partnership model for innovation in products and services: the project partners (academic and business) define the projects by themselves, and the business side covers at least half of the project costs. Econometric studies have investigated the effect of CTI policy on the performance of private firms, and they have shown that this policy improved the innovation performance of firms in terms of both R&D intensity and sales of innovative products. The effect on labor productivity has also been positive (Arvanitis, Hollenstein, and Marmet 2006). The CTI's bottom-up approach to strengthening technology transfers between academic and firms, its coaching services for start-ups, and its nationwide education program for would-be entrepreneurs are mainly responsible for this effect.

The following sections explore the relevant policy responses beyond the general mechanism just described.

Supporting the Knowledge-Transfer Mission of the Universities of Applied Sciences To deal with this problem, CTI acts as a coach to the UASs to foster cooperation between them and the business world. This measure promotes joint projects by funding the salaries of university researchers. CTI also helps the UAS identify and develop areas of focus and major topics of interest in selected fields. Using the results of evaluations by experts, the Federal Department of Economic Affairs awards a national competence "seal," which signals the particular research competences of the university. The question remains, however, whether these minor policy adjustments are sufficient to increase the collaborative capacities of the UASs or, whether at some point, their radical transformation into research universities will be considered inevitable. The question is whether the country can afford this change. The problem is systemic, because no tradition of tuition fees exists in Switzerland, so that any upgrading and deepening of tertiary education in the UASs could be accomplished only at the expense of federal and cantonal public budgets.

Creating New Models for IP Management The management of IP as part of technology-transfer activities is fast becoming a policy issue. A new model is currently being discussed for cooperative research and codevelopment that will be tested in few cases. If the model succeeds, it would become a standard model to help IP management in other relevant cases. This model involves making a full transfer of IP to industry, with a clear definition of the field of use, together with the granting of a license outside the field of use to the university; the university will charge very high overhead costs (about 40 percent). The rationales for this model are as follows: (a) the industry considers the complexity of IP negotiations a major impediment to research cooperation; (b) very few cooperative research ventures lead to IP of high market value; and (c) the increased overhead cost is not considered an obstacle for companies to engage in cooperative research, although this issue is rather uncertain in the case of SMEs.

Targeting SMEs A new policy emphasis is the involvement of SMEs in university-industry relations. Given the usual drawbacks as documented in the 2006 KOF innovation survey (Arvanitis, Hollenstein, and Marmet 2006), the goal is to help SMEs better articulate their research needs and find research partners. CTI provides funding to support the creation of knowledge- and technology-transfer consortia involving all technology-transfer organizations (TTOs) of a given region (Alliance, for instance, involves the TTOs of the universities of Geneva, Lausanne, Neuchâtel, and of Italian-speaking Switzerland; of the EPFs; and of the university hospitals of the cantons of Geneva and Lausanne). The consortia create a platform to reinforce the interface between SMEs and academic research. This activity involves, for example, recruiting technology officers who know well a particular industry and who will help SMEs articulate their research needs, identify an academic partner, and manage the collaboration.

A consortium allows entities to share the costs of hiring several technology organizations (specialized in different fields) and increases the probability that SMEs will find a good partner because of the broad view and knowledge that multiple technology organizations within a TTO offer.

Conclusion

Framework conditions and structural characteristics are more important than innovation policies as driving factors of the performance of the Swiss national innovation system: excellence of science, S&T skills and competences, ATs, innovative performance of SMEs, financial development, and clusters are important characteristics explaining the high innovative performance of the country. Indeed, the assertion of largely insufficient knowledge and technology transfer between corporations and science institutions in Switzerland is not supported by empirical evidence (Arvanitis, Hollenstein, and Marmet 2006).

Innovation policy matters, however, and its effect is particularly clear when we look at the recent history of the Swiss innovation system:

- *Policy matters during recession periods*. Switzerland experienced severe macroeconomic recessions (actually a double shock) during the 1990s, and as a result, R&D intensity declined dramatically in relative terms (while public R&D declined in absolute terms). Degradation of innovative performance logically followed this period, and no R&D policy existed to play a countercyclical role and help financially constrained firms maintain R&D capacities during the recession period.

- *Policy matters during revolutionary periods*. The information and communication technology revolution provided extraordinary economic opportunities, and some countries with vigorous public policy exploited those opportunities quite successfully. Recent history of the high-tech revolution shows the centrality of public policy in creating strategic orientations and rapidly redirecting resources toward new objectives and fields promising the highest returns. Public policy can be very useful in overcoming coordination failures that may impede a whole system from moving toward new fields and topics. This public policy was not used in the case of Switzerland. This kind of mission-oriented policy is new to policy makers and industry managers in Switzerland. Therefore, strategic capacity in this regard is weak, and no real willingness exists to generate top-down programs to help the system as a whole to move and transform its knowledge base.[12] Such reticence may be a good thing because many governments have experienced expensive failures in trying to select fields and pushing industry to invest in them. However, an interesting question for the future is whether the economy will respond positively to the outstanding basic research capacities in nanotechnology. No policy initiative is expected to support initial market dynamics or to create incentives for the private sector to invest in those fields. Will market incentives alone work sufficiently well in pushing the Swiss economy toward these new important areas?
- *Policy matters at any time to correct the largest market failures.* Such is usually the case for resource allocation to R&D, especially with regard to SMEs and start-ups. Here the Swiss policy has been active through indirect and neutral mechanisms and is seeking to expand its scope of intervention. Some policy objectives are currently being discussed to improve the interface between universities and small firms, such as a deeper involvement of UASs in technology-transfer activities and

[12] To a minor extent, the CTI follows a top-down approach to promote cooperation in specific research areas: innovation for successful aging, nanoscale technologies, and life science and medical technologies. However, the proportion of public funding allocated to this approach is small.

better integration of SMEs into knowledge and technology flows. This goal should be achieved through boosting the funding of R&D at public research institutions by substantially increasing the resources of the CTI. However, the Swiss economy is engaged in a process of restoring better control of public spending—to keep the deficit down to 1.25 percent of GDP (OECD 2005a)—making it politically difficult to aim at a large increase for public funding of R&D.

As a general conclusion, the Swiss case (as well as those of other nations) makes clear that many institutional models can be used to support technology transfer between universities and industry. National laws and the legal environment play an important role in enabling and facilitating the process. However, the most important factors are the types of private arrangements developed at the firm level to increase absorptive capacities and at the university level to achieve a good balance between making technology transfer more effective and maintaining the basic mission (pure and long-term basic research and education).

The fact that the level of capacity of the university—that is, the capabilities of the university to create rules and organizational structures in a decentralized way as well as the managerial competence and autonomy of the central university administration—is more important than the dictates of national laws is clearly demonstrated by the experience accumulated following the Bayh-Dole Act (David 2005). Several well-known studies on leading U.S. research universities have found that biomedical patents issued to U.S. universities between 1969 and 1979 increased by 123 percent (well before the Bayh-Dole Act was passed in 1980). Moreover, the first TTO did not open its doors in 1981; it had, in fact, been in existence for 56 years at the University of Wisconsin. Thus, the Bayh-Dole Act merely provided a legal framework for behavior and strategies that had already existed for a long time in some successful universities.

References

Agrawal, Ajay, and Iain M. Cockburn. 2002. "University Research, Industrial R&D, and the Anchor Tenant Hypothesis." NBER Working Paper 9212, National Bureau of Economic Research, Cambridge, MA.

Arvanitis, Spyros, Heinz Hollenstein, and David Marmet. 2006. "Innovative Activities in Switzerland: Strengths and Weaknesses." Background report, Konjunkturforschungsstelle der ETH Zürich, Zürich.

CSTB (Computer Science and Telecommunications Board). 1999. *Funding a Revolution*. Washington, DC: National Academies.

David, Paul A. 1998. “Knowledge Spillovers, Technology Transfers, and the Economic Rationale for Public Support of Exploratory Research in Science.” Background paper for the European Committee for Future Accelerators, Geneva.

———. 2005. “Innovation and Universities’ Role in Commercializing Research Results: Second Thoughts about the Bayh-Dole Experiment.” SIEPR Discussion Paper 04-27, Stanford Institute for Economic Policy Research, Stanford, CA.

David, Paul A., Dominique Foray, and W. Edward Steinmueller. 1999. “The Research Network and the Economics of Science: From Metaphors to Organizational Behaviours.” In *The Organization of Economic Innovation in Europe*, ed. Alfonso Gambardella and Franco Malerba, 303–42. Cambridge, U.K.: Cambridge University Press.

David, Paul A., and Paul L. Stoneman. 1985. “Adoption Subsidies vs. Information Provision as Instruments of Technology Policy.” CEPR Publication 49, Center for Economic Policy Research, Stanford, CA.

Hall, Bronwyn H. 2004. “University-Industry Research Partnerships in the United States.” In *Rethinking Science Systems and Innovation Policies: Proceedings of the Sixth International Conference on Technology Policy and Innovation*, ed. Jean-Pierre Contzen, David Gibson, and Manuel V. Heitor. West Lafayette, IN: Purdue University Press.

Jaumotte, Florence, and Nigel Pain. 2005. “Innovation in the Business Sector.” OECD Economics Department Working Paper 459, Organisation for Economic Co-operation and Development, Paris.

Lécuyer, Christophe. 1998. “Academic Science and Technology in the Service of Industry: MIT Creates a ‘Permeable’ Engineering School.” *American Economic Review* 88 (2): 28–33.

Mowery, David C., and Timothy S. Simcoe. 2002. “Is the Internet a U.S. Invention? An Economic and Technological History of Computer Networking.” *Research Policy* 31 (8–9): 1369–87.

Nelson, Richard R., and Paul Romer. 1996. “Science, Economic Growth, and Public Policy.” In *Technology, R&D, and the Economy*, ed. Bruce L. R. Smith and Claude E. Barfield, 49–74. Washington, DC: Brookings Institution.

Nelson, Richard R., and N. Rosenberg. 1994. *American Universities and Technical Advances in Industry*. CEPR Publication 342, Center for Economic Policy Research, Stanford, CA.

OECD (Organisation for Economic Co-operation and Development). 2005a. *Economic Survey of Switzerland*. Paris: OECD.

———. 2005b. *Science, Technology and Industry Scoreboard*. Paris: OECD.

OFS (Office Fédéral de la Statistique). 2005. *R-D: Les Dépenses de la Confédération, Indicateurs Science et Technologie, Finances et Personnel*. Neuchâtel, France: OFS.

Rosenberg, Nathan. 2005. "Science and Technology: Which Way Does the Causality Run?" Lecture at the Science, Technology, and Society Center, University of California, Berkeley, October 25.

Saxenian, AnnaLee. 2001. "Transnational Technical Communities and Regional Growth in the Periphery." Saint Gobain Centre for Economic Research, Paris.

Sumell, Albert J., Paula E. Stephan, and James D. Adams. 2005. "Capturing Knowledge: The Location Decision of New PhDs Working in Industry. http://www.nber.org/~sewp/Stephan-Sumell-Adams_Capturing.Knowledge.NBER-2-06.pdf.

Zellner, Christian. 2005. "The Origins of High-Technology Start-Up Companies at EPFL." École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland.

CHAPTER 4

University-Industry Links and U.K. Science and Innovation Policy

Alan Hughes

In the United Kingdom, as elsewhere in the industrial and developing world, more attention is being paid to the role that universities can play in supporting innovative performance and productivity growth. The U.K. Science and Innovation Investment Framework for 2004 to 2014 is based on the proposition that

> Harnessing innovation in Britain is key to improving the country's future wealth creation prospects . . . [Britain] must invest more strongly than in the past in its knowledge base and translate this knowledge more effectively into business and public service innovation. Securing the growth and continued excellence of the U.K.'s

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The author is a member of the Council for Science and Technology, the senior advisory body to the U.K. government on science and technology policy. The views in this chapter are his own and should not be attributed to the Council for Science and Technology. The author is grateful to the Cambridge-MIT Institute for financial support under the Innovation Benchmarking and Universities and Local Systems of Innovation projects and to his colleagues Andy Cosh and Richard Lester for many helpful discussions on innovation and university-industry links.

> public science and research base will provide the platform for successful innovation by business and public services. (Her Majesty's Treasury, DTI, and DfES 2004, 5)

The notion that the translation of science into business innovation in the United Kingdom is ineffective has deep roots:

> [T]he small band of British scientific men have made revolutionary discoveries in science; but yet the chief fruits of their work have been reaped by businesses in Germany and other countries, where industry and science have been in close touch with one another. (Marshall 1923, 101–2, fn 1).

A problem that is so deep rooted as to be an issue during two periods a hundred years apart is unlikely to have an easy or straightforward policy solution. This chapter assesses the nature of university-industry links in the United Kingdom and outlines the current policy approach. The comparator in this respect is the United States, the current role model for U.K. policy in this area. The nature of that role model is often misinterpreted. One aspect of the role, namely that connected with licensing, patenting, and high-tech entrepreneurial spinoffs, is overemphasized. Other aspects—the differentiated role of U.S. universities, technology absorption by key user sectors such as retailing and wholesaling, and the important support role of public expenditure and procurement policy—are neglected (Hughes 2003). This chapter attempts to demonstrate the full range of university-industry interactions in the two countries. It also attempts to place those links in perspective within the range of sources of knowledge for business innovation. A brief overview of relevant U.K. policy locates university-industry links within the overall policy framework for innovation and science, engineering, and technology (SET). A key to developing successful policy is to integrate existing and potential policy levers as much as develop new initiatives; there is a potential role for more effective use of public procurement in this area.

The Diverse Nature of University-Industry Relationships

Despite abundant evidence testifying to the diverse nature of university-industry relations, current discussions on innovation policy tend to focus on those few directly concerned with commercialization (patenting, licensing, and spinoffs). It is useful, therefore, to map out the range of actual interactions.

At least four potentially separable kinds of interactions work at the university-industry interface (Lester 2005). First is the basic university role of educating people and providing suitably qualified human capital for the business sector. Second is the role that research activity plays in increasing the stock of codified knowledge that may have useful or commercial elements. Third is a role in problem solving in relation to specifically articulated business needs. Fourth is a group of what one might term *public space functions*. These functions are relatively neglected but distinctive features of the role of universities in the economic and intellectual systems of nations. They include a wide range of mechanisms for interaction between the university staff and the business community. They range from informal social interactions to specially convened meetings and conferences, centers that promote entrepreneurship and entrepreneurship activities, and the exchange of personnel, including through internships. Each of these public space functions promotes a range of activities between the business community and the university sector. They may lead to the transfer not only of codified but also of tacit knowledge and to the establishment of relationships that may feed back into the other three roles.

Recognizing the different elements that individual universities stress is also important. These elements may reflect a university's particular mission as well as the economic circumstances of the university's locality or region and the role it chooses to play in relation to them. In a recent international collaborative study of regional patterns of university interactions, the Local Innovation Systems Project at the Massachusetts Institute of Technology (MIT) developed a useful typology for the ways in which different dimensions of activity may develop and be most appropriate to different local economic development pathways (Lester 2005).

One pathway focuses on the creation of new industries. The most important interactions occur in circumstances that emphasize leading-edge science and engineering research, aggressive technology licensing policies, and promotion or assistance of entrepreneurial businesses. Such circumstances may also lead to great emphasis on participation in standard setting and other activities that promote the rapid diffusion of particular technologies.

A second pathway emphasizes the role of universities, where the regional development strategy is focused on importing or transplanting industries, for instance, into formerly declining localities. In those circumstances, curricula that are responsive to the needs of the transplanted or imported industries (and associated education and human resources developments) might receive more emphasis, as might technical assistance for the emerging subcontracting and supplying industries that those industries may require.

A third pathway emphasizes building bridges. To the extent that the local development strategy involves diversifying from existing strengths to new technological ones, the university role may emphasize making bridges between otherwise disconnected actors in the local system. It can also focus on filling structural holes in the networks of activity and creating new industrial identities.

A fourth pathway may apply where existing industries are upgrading. In these circumstances, problem solving and the use of faculty for consulting and contract research may assume significance. Associated activities include those designed to upgrade the skills of the educated labor force and those concerned with global best practices for scanning foresight exercises and developing user-supplier forums.

The first key point here is that the variety of interrelationships allows a rich set of interaction patterns. There is no one true way. Although regional patterns are emphasized here, the nature of the relationships varies sectorally. The second key point is that in each industry or region, universities will be only one among many sources of knowledge inputs. Their potential influence must be viewed in this wider systems context.

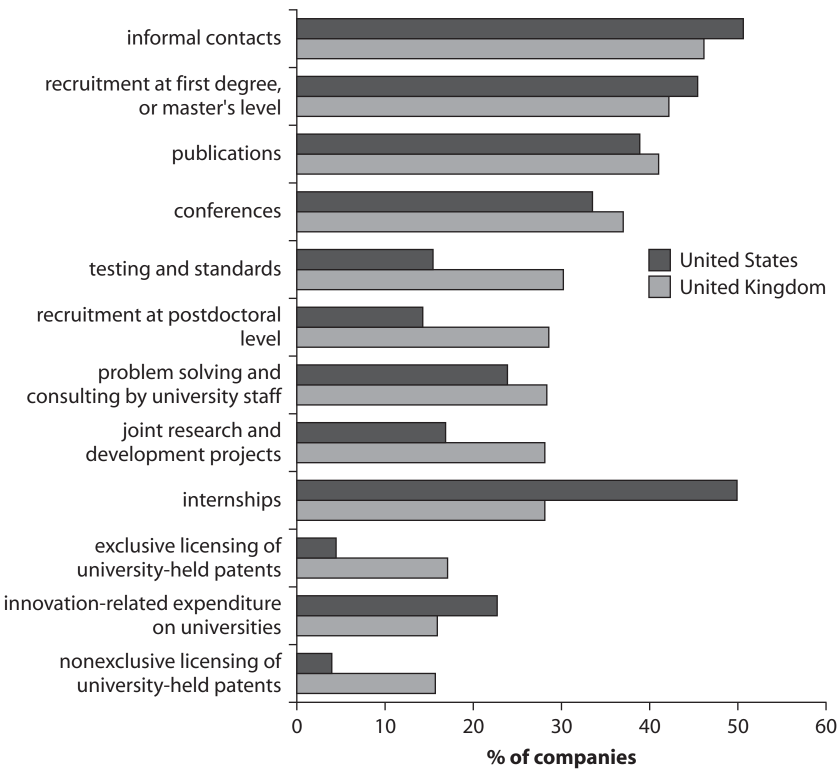
University-Industry Links: A U.S.-U.K. Comparison

A recent survey by the Centre for Business Research (CBR) at the University of Cambridge, United Kingdom, and the Industrial Performance Center (IPC) at MIT indicates the variety of mechanisms by which university activity may affect innovative performance in industry. The survey benchmarked innovation activity in the two economies (Cosh, Hughes, and Lester 2006). The only survey to date that compares the U.K. and the U.S. systems, it provides the most recent data available for both countries.

The survey was carried out from March to November 2004 by telephone. Response rates were about 19 percent in the United States and about 18 percent in the United Kingdom. In 2005, a top-up survey was carried out by mail for the largest firms in both countries. The survey instrument contains about 200 questions and generates about 300 variables per firm. The final sample consisted of 2,129 U.K. firms and 1,540 U.S. firms. The results reported here relate to a sample of 2,298 businesses: 1,149 from each country matched by size, sector, and age. This sample makes it possible to compare the countries without adjusting for differences in the size, sector, or age of businesses.

The survey inquired about interactions that contributed to innovative activity. The responses are summarized in figure 4.1. They show a similar pattern of interaction in the two countries. In both countries, businesses report engaging with universities through a very broad range of mechanisms. Informal contacts are most frequently cited, followed by what may be regarded as conventional interactions involving recruiting graduates, using publications, and attending conferences. Licensing and patenting are among the least frequently cited interactions that contribute to innovative activity across the matched sample. Strikingly, with a few exceptions such as internships, U.K. firms report such interactions more frequently. There is little here to suggest that, with those exceptions, the

Figure 4.1. University-Industry Interaction Contributing to Innovation

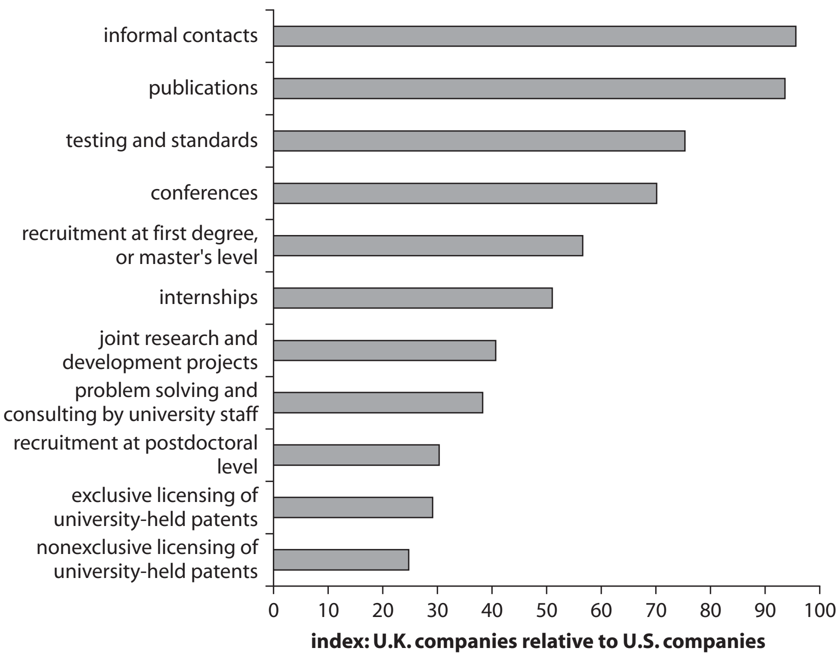


Source: Cosh, Hughes, and Lester 2006.

frequency of interaction is below par in the United Kingdom or that particular policy attention is required to increase it.

In addition to asking whether a particular type of interaction occurred, the survey asked about the importance attached to that interaction. Examining the relative results in the two countries is useful. In figure 4.2, a score of more than 100 on the horizontal axis means the relevant interaction is rated as important relatively more frequently in the United Kingdom than in the United States. The first point that emerges clearly is that, whereas U.K. businesses more frequently report taking part in most types of interaction, U.S. companies more frequently rate their interactions as highly important for their innovative activities (that is, the relative score is less than 100). U.S. companies more frequently place high importance on the admittedly infrequent licensing interaction, as well as on joint research and development (R&D) and problem solving and on postdoctoral and graduate recruitment and internships. The last two are also quite high-frequency interactions, and the U.S. firms are also much more likely to use internships than are the U.K. firms. The differences

Figure 4.2. University-Industry Interactions Regarded as Highly Important for Innovation



Source: Cosh, Hughes, and Lester 2006.

between the two countries are less marked for the much more frequent activities of informal contacts and publications. Further evidence for the view that the depth and quality of relationships distinguishes the United Kingdom from the United States is the separate finding from the survey that U.S. businesses are more likely to make innovation-related expenditures to support their university links (Cosh, Hughes, and Lester 2006).

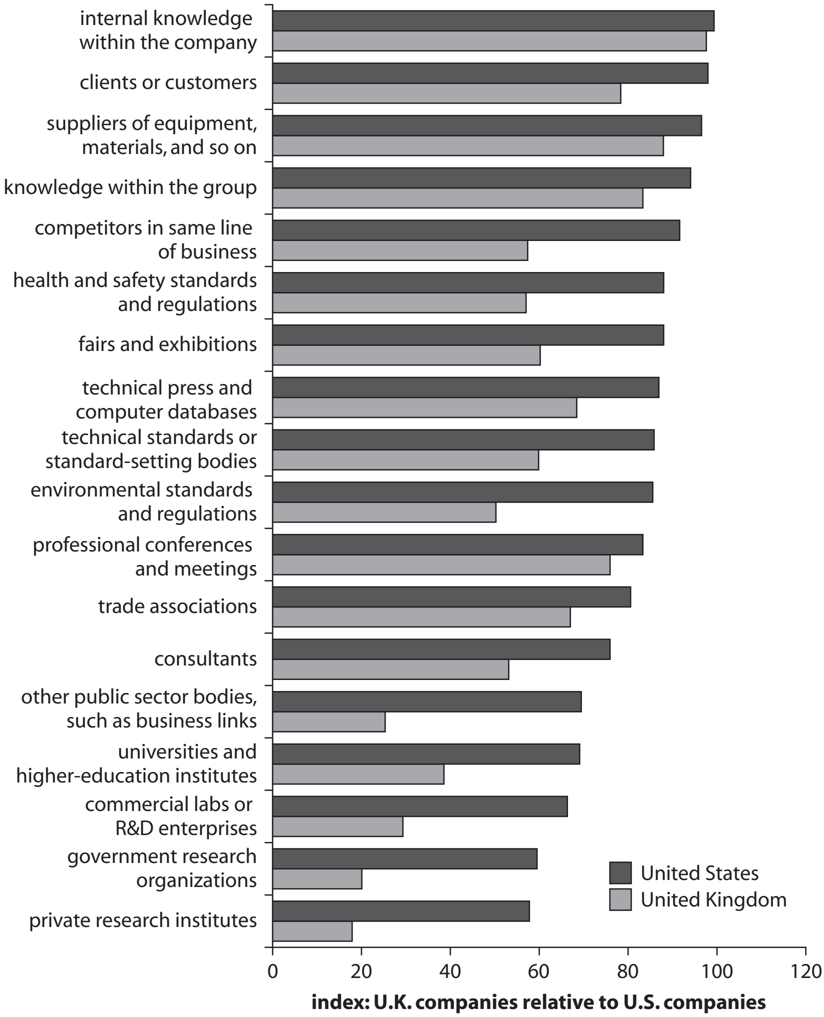
The patterns revealed in figures 4.1 and 4.2 suggest that, in terms of the frequency of interactions, far more is at stake than licensing, spinoffs, and R&D. Equally, the relatively high importance that the U.S. firms place on all university interactions and particularly on licensing, joint R&D, and problem solving suggests a need to address the quality of these relationships.

In thinking about the relative weight to give university-industry interactions in the promotion of innovation and productivity, we must look at the context of those interactions—the broader system of business interactions related to innovation. The CBR and IPC survey therefore asked businesses about their overall sources of knowledge for innovation. The results, summarized in figures 4.3 and 4.4, present the frequency of use of various sources of knowledge for innovation in the two countries and the relative importance attached to each source by U.K. businesses as compared with U.S. businesses.

Figure 4.3 shows that in both countries universities are ranked very low in frequency of use. Customers, suppliers, competitors, and internal organizational knowledge are the dominant sources of knowledge for innovation. In all cases, the U.K. businesses claimed to be more frequent users of external sources than did the U.S. businesses. However, figure 4.4 shows that, as with university interactions, the U.S. companies more frequently placed more importance on external knowledge sources than did the U.K. businesses. For all but three sources (competitors, in-house knowledge, and clients or customers), U.S. companies were more likely to rate sources as highly important than the U.K. companies. This finding was particularly true for the public sector, university, and private research institute sources, even though these sources were used somewhat less frequently.

In general, these findings imply that although the use of external sources appears to be more important in the United Kingdom, the value or importance placed on those relationships is higher in the United States. The implication is that U.S. firms give greater importance to open innovation system sources that are outside the immediate industrial context.

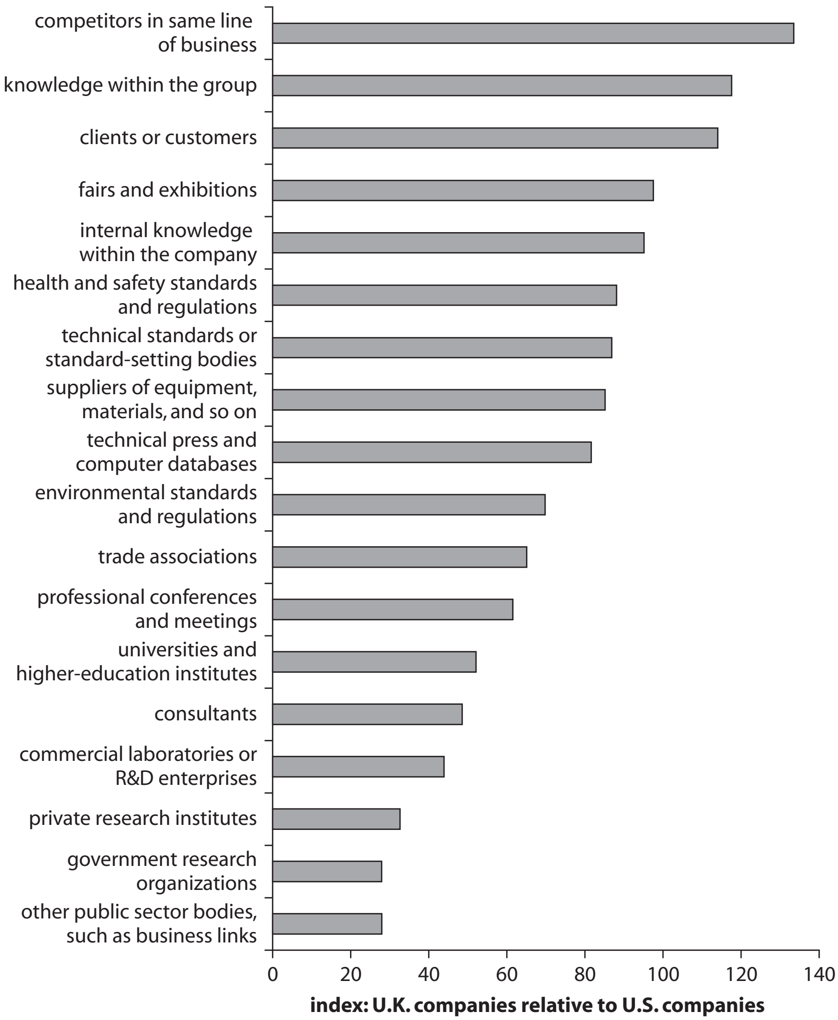
Figure 4.3. Use of Sources of Knowledge for Innovation



Source: Cosh, Hughes, and Lester 2006.

Further analysis of the survey data focused on variations in the importance attached to particular university interactions and to the frequency of use of sources across size classes. It shows that the U.S. firms in all size classes appear more likely to rate universities highly as sources of knowledge. However, it also shows that the smaller U.K. firms lag most behind U.S. counterparts in attributing significant importance to univer-

Figure 4.4. Sources of Knowledge for Innovation Regarded as Highly Important by Users of That Source



Source: Cosh, Hughes, and Lester 2006.

sities as a source of innovation-related knowledge (Cosh, Hughes, and Lester 2006).

This brief overview of some key findings of the CBR and IPC survey has a number of implications for policy. In both countries, innovation-related interactions between universities and businesses are a small part of the overall innovation system and must be viewed in that light. This is not to deny that for some sectors such links may be significant. Rather it is to emphasize the need to craft university-focused innovation policy with close attention to the full set of relevant interactions. A second implication arises from the observed relative depth of—and degree of importance attached to—such interactions in the United States. If the United States is to be the policy role model, attention should be paid to raising the quality of interactions in the United Kingdom rather than increasing their incidence. Finally, it appears that in the United Kingdom smaller businesses are less likely to be involved in and place importance on university interactions. These findings and the importance of focusing beyond spinoffs and licensing confirm the qualitative arguments made in the recent innovation policy review carried out by Richard Lambert (Her Majesty's Treasury 2003).

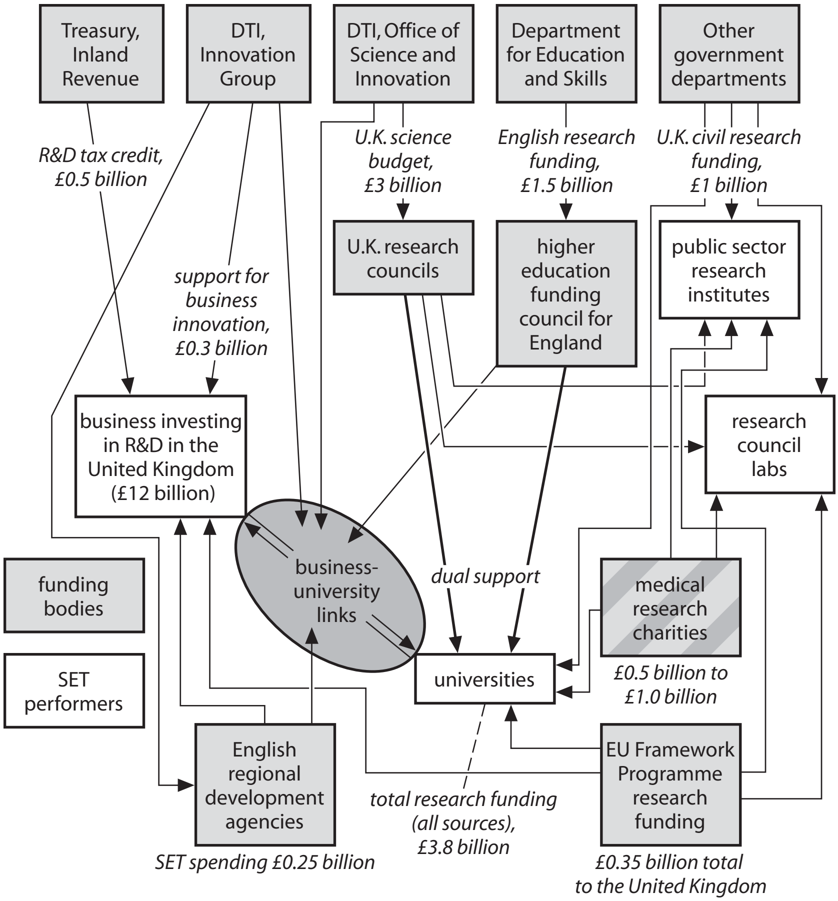
The main conclusions of the Lambert review relevant to this chapter were that the principal challenge to the effective exchange of knowledge between U.K. businesses and universities lies in raising the demand by business for quality research from all sources—including universities. The report argued that there was a case for making greater business inputs into university courses and curricula in the United Kingdom. It also made a strong plea for shifting R&D support policy to promote interactions between universities and smaller firms.

U.K. SET Policy and University-Industry Links: A System Overview

To understand the nature of policy intervention in university-industry links in the United Kingdom, setting the links in the context of overall science policy and of the U.K. R&D system is useful. To avoid complications of detail that arise when considering the nature of policy in devolved national administrations, the analysis shown in figure 4.5 is for England alone.[1] Figure 4.5 provides a schematic overview of the public organizations and the major charitable organizations that fund SET activity and the organizations that carry it out. Funders are shown in the shaded boxes, along with indications of the scale of funding levels in 2002. SET performers in the public and private sectors are shown in

[1] I am very grateful to Daniel Storey of Her Majesty's Treasury for this diagrammatic exposition. In 2006, the Office for Science and Technology was renamed the Office of Science and Innovation. Its new name is used in the diagram.

Figure 4.5. Funding and Performing SET in England: University-Industry Links in Context



Source: See footnote 1 on p. 80.

unshaded boxes; they cover the business sector, universities, public sector research institutes, and the U.K. Research Council laboratories.

There are many actual and potential, direct and indirect policy influences on university-business links. The most important route is through the dual support system. It provides core university funding through two mechanisms, which, along with charitable funding of medical research, account for about £3 billion of the total expenditure on university research funding (about £3.8 billion). The first mechanism is direct block grants from the Department for Education and Skills through the Higher

Education Funding Council for England. These grants support research activity with allocations that are linked to university size and performance in a periodic research assessment exercise. The extent to which the funds are linked to university-business activities is essentially a matter for individual universities. The second leg of the dual funding system is provided by the Office for Science and Innovation through the seven U.K. research councils,[2] which allocate project- or program-specific funds to universities, research council labs, and public sector research institutes on the basis of scientific peer review of competing bids. The extent of specific university-business interaction here depends on council policy initiatives related to the award process.

Government policy concern about the extent to which this dual flow of funds was too dominated by scientific peer review and too little connected to business uses has led to periodic attempts to address both problems (for example, HEFCE 2003a, 2003b). It has also led to a series of initiatives, such as the Higher Education Innovation Fund (HEIF), designed to provide resources to develop a so-called third leg of university funding. The initiatives are based on encouraging entrepreneurial spinoffs and raising income from commercialization activities such as licensing and patenting. They are discussed in more detail in the next section.

In addition to those primary funding sources, universities attract research funding on a smaller scale from the Department of Trade and Industry (DTI) to support innovation activity and from the nine regional development agencies (which are funded by the DTI). Universities also compete for funds under a variety of European Union programs. Those funding routes are frequently linked to schemes designed to promote specific national or regional university interactions or to promote research collaboration across Europe. Of £3.8 billion in university research funding, about £300 million comes directly from the business sector.

Businesses carry out about £12 billion per year in R&D. The main direct policy support here comes from the R&D tax credit (worth about £500 million a year) and from a range of business support programs delivered regionally or nationally by DTI. Such programs were worth about £300 million in 2004/05. They are discussed further below.

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[2] The seven councils are the Economic and Social Research Council, Engineering and Physical Sciences Research Council, Arts and Humanities Research Council, Particle Physics and Astronomy Research Council, Biotechnology and Biological Sciences Research Council, Medical Research Council, and Council for the Central Laboratory of the Research Councils.

Civil public sector expenditure on R&D shown in figure 4.5 (amounting to about £1.8 billion) was augmented by about £500 million of defense-related public sector R&D (not shown). Only about £400 million of this combined total was channeled through higher education or research council institutions. The rest was either conducted inside the relevant department (about £900 million) or in the U.K. business sector (about £900 million) with a small balance carried out overseas. The effect that publicly procured R&D could have on university-industry links from the business demand-pull side is thus considerable. For instance, an element of this procurement could be used to promote knowledge-based firms linked to the science base. This underdeveloped aspect of U.K. innovation policy is discussed further in the next section.

The complexity of the system poses obvious problems of coordination. In developing SET policy and university-business links, the U.K. government has, therefore, developed a long-term program designed to strengthen the science base, rationalize business support policy, raise the overall R&D effort, and strengthen commercialization activity and university links.

Science and Innovation Investment Framework for 2004 to 2014

The investment framework for science and innovation sets a target of raising total U.K. R&D from 1.9 percent of GDP to 2.5 percent of GDP by 2014. The broad structure is shown in table 4.1. The year-on-year growth of public science spending was 10 percent from 2003/04 to 2005/06. The commitment in the science and innovation investment framework is that the level of public spending on the science base will grow faster than the rate of growth of GDP over the framework period, rising from 0.7 percent to 0.8 percent of GDP. Reaching the 2.5 percent target nationally by 2014 clearly requires a substantial matching investment by the private sector, which must raise its R&D from 1.2 percent to 1.7 percent—in a period of stagnant or declining levels of private sector R&D. The share of overall private sector R&D in GDP fell from 1.4 percent in 1985 to 1.2 percent in 2002. R&D in the private sector is also heavily concentrated; only a handful of large U.K. firms in a few sectors have intensive R&D expenditures (DTI 2005). The pharmaceutical and aerospace sectors account for 23 percent and 10 percent of private sector R&D, respectively.

There is little sign that the target will be met by the large R&D spenders. Moreover, R&D is internationally mobile. Increasing attention has therefore focused on the potential role of newer, technologically based

Table 4.1. The 10-Year Science and Innovation Investment Framework R&D Target

	R&D investment as percentage of GDP	
Type of investment	*2004*	*2014*
Science base	0.4	0.5
Other government R&D	0.3	0.3
Private sector	1.2	1.7
Total	1.9	2.5

Source: Her Majesty's Treasury, DTI, and DfES 2004.

small and medium enterprises (SMEs) in filling the void. There is, however, an order of magnitude problem. Data on independent SME R&D are subject to considerable margins of error, but even generous estimates suggest that the total is only between £400 million and £600 million—a minor fraction of the £12 billion spent by the private sector in 2004/05.

Whatever the likelihood of meeting the target, doing so may be far less important than other aspects of the framework. First, R&D is an input, and what matters for commercialization is how effectively it is converted into output. Second, that conversion requires major complementary investments in design, marketing, and human capital developments (Cox 2005), effective access by business to the full range of knowledge sources described earlier, and the design of a public space architecture to enable universities to play their parts across the full range of interactions identified earlier (Lester and Piore 2004).

It is worthwhile to highlight a few of the more important policy-related elements of the innovation and investment framework here. First, in relation to university spending in particular, the investment framework for science and innovation makes a basic commitment to the full economic costing of university research projects. This commitment is an important element in maintaining a sustainable science base, because it prevents the undercosting of projects and the cross-subsidization of them from other sources of university income—typically at the cost of essential overhead infrastructure. Second, in relation to third-leg funding, there has been a realignment of the HEIF and a rationalization of the DTI innovation support policies (or *products*, as they are now known). Third, the Technology Strategy Board has been introduced to play a key intermediary role between science and technology projects with market potential and the business sector.

In its realigned third phase, HEIF will involve approximately £240 million in funding to higher education institutions from August 2006 to

July 2008. The intent is to promote activities in the university sector of direct and indirect economic benefit to the United Kingdom. The fund is designed to support knowledge-transfer activities that are unlikely to generate large net income for universities and, therefore, are not attractive investment propositions for the universities. A national scheme, it encourages bids with regional involvement to foster connections between the university sector and regional economies. The scheme avoids a problem that many newly introduced schemes face: a lack of sustainable human capital to support them. It does so by allocating new funds under phase 3 of HEIF on a formulaic and predictable basis. More predictable funding should allow the recruitment and retention of skilled staff members. A small amount of the funding is reserved for a competitive allocation. This portion is designed to encourage new and innovative approaches and to encourage collaborative activities across higher education institutions, so as to get economy-of-scale gains from knowledge-transfer activities and to capitalize on best practices. These changes are designed to encourage an increased degree of quality and depth in university-industry relations, which the CBR and IPC survey suggests is required.

Before the introduction of the science and innovation investment framework, the DTI innovation support program was characterized by a plethora of schemes and products with varying or ill-defined objectives and different modes of operation and delivery. As a result of an innovation review (DTI 2003) carried out before the development of the framework, the DTI innovation products have been rationalized into three. First is the grant for R&D, which used to be called the SMART (Small Firms Merit Award for Research and Technology) program. It provides about £30 million per year to support SME funding for innovation activities in the early development stages before commercialization. This product is therefore a continuation of a very successful scheme that has operated effectively for many years (Cox, Hughes, and Spires 2002) and is part of the useful underlying support system for SME R&D activity that is linked to early-stage commercialization from the science base.

The second DTI innovation product is the Knowledge Transfer Network. This product supports the formation of groups of knowledge-transfer organizations, which were formerly known as Faraday Partnerships. They are intended to strengthen the relationship between sector-based businesses and universities that specialize in relevant technologies. They develop pooled sources of knowledge on technology development and foster collaboration between business partners and universities on a national rather than a regional scale. This activity includes, among other things, a range of metrology and related issues and the creation of standards for effective network activity. The product is designed to help address the tailoring of specific university-industry relationships to sector needs as well as the encouragement of an open system in the connections between the relevant partners in the sectoral framework. There is a clear and unresolved tension between this national sector-based approach and the various attempts to develop a regional focus in university-industry links.

The third central product is based on Knowledge Transfer Partnerships. This program, formerly known as the Teaching Company Scheme, is worth £20 million per year. It is a substantial scheme with about 1,000 projects under way; the projects partner universities with firms to resolve particular technology-based projects. It too is an important initiative; it links the university base, through human capital relations and internships, with individual firms wishing to solve particular problems. This scheme relates directly to that dimension of university-industry links identified in the survey results that emphasizes customized, problem-solving, contract research. It also has a successful track record (SQW Limited 2002).

Taken as a whole, these products address a number of potential problems highlighted earlier. They have been in place for some time, and the commitment of resources remains stable. Notwithstanding their merits, it would appear that additional effort must come from a more focused commitment to these products as part of the overall technology strategy embedded in the long-term framework.

A new addition to the architecture that is designed to enhance inputs from the science base is the Technology Strategy Board (TSB). It is designed to play a key role in the selection of priority areas for innovation support expenditures, through the DTI Collaborative Research and Development project program (TSB 2006). About £250 million will have been committed by TSB by 2006; the amount will rise in subsequent years. The board largely consists of members from the private business sector, including the venture capital community. Its role is to encourage the development of technology emerging from the science base that is closest to market possibilities, through collaborative bids for funding. Those market possibilities are to be chosen with a view to the likely scale of potential markets available globally in which the United Kingdom has potential for augmenting or developing world-class competitive capacity. The initial program activities focus on seven key areas: electronics and photonics, advanced materials, information and communications technology, bioscience and health care, sustainable production and consumption, emerging energy technologies, and design engineering in advanced manufacturing (TSB 2006). The board represents an important new initiative in terms of focusing expenditure in relatively key areas from a combined business and technology perspective.

The size of the budgets committed in these areas is substantial in public policy terms. Their impact on the inputs from the science base by SMEs could, however, be considerably enhanced if public sector extramural R&D could be used more effectively. The opportunity to enlist those expenditures to harness technologies from the science base has been relatively neglected in the United Kingdom, compared with successful schemes using public procurement measures in the United States such as the Small Business Innovation Research (SBIR) Program (Connell 2004, 2006).[3] Attempts in the United Kingdom to develop a similar program have so far failed to generate significant results. The reasons are closely related to two key factors. First, the extent to which opportunities are available is intermittent, and the terms on which they are accessible are relatively opaque. Second, in the past, a strong element of cofunding has been required in obtaining U.K. public sector procurement support. This situation contrasts with that in the United States, where full cost contracts are awarded.

The potential benefits of extending and making this scheme more effective in the United Kingdom are twofold. First, the amount of funding potentially available to mobilize technologies from tertiary-level institutions would be substantially enhanced. Second and more significant, the contract nature of the relationship helps develop reputation and competence in the early stages of start-up. The existence of a contract, as opposed to a grant, both helps formalize the development of early-stage businesses and makes those businesses more attractive propositions when they seek funding for further development from the financial sector and other sources (Connell 2004, 2006).

This potential role for public procurement, which was relatively neglected in the original Science and Innovation Investment Framework report, has been given more emphasis in the follow-up program (Her Majesty's Treasury and others 2006). Thus, in the 2004 and 2005 budgets, moves were taken to make it mandatory for government departments and agencies to place 2.5 percent of their extramural R&D contracts with SMEs through the Small Business Research Initiative (SBRI), as well as to develop a new National Health Service research strategy to

[3] For more information about the SBIR Program, see http://patapsco.nist.gov/ts_sbir/.

attract business-related R&D on health (Her Majesty's Treasury and others 2006). It is too soon to evaluate these latest proposed changes. The first change implies buying about £50 million of government research from smaller firms.[4] It still faces concerns about how effective delivery will be in practice, given the lack of effective, simple procedures and the lack of coordination in the delivery of the initiative compared with the U.S. SBIR Program (Connell 2006).

Conclusions

University-industry links and their potential role in innovation must be viewed as part of a complex system. These links are only one of the sources of knowledge from which businesses derive information on technologies relevant to their production processes and competitive positions. In the development of university-industry links, it is important to recognize the distinctive public space that universities can provide and not focus only on issues relevant to licensing, spinoffs, and R&D expenditure.

Insofar as the United States is viewed as a role model for the United Kingdom, it appears that within existing university-industry relationships, their depth and quality, not their number, are the most significant differences. These differences appear to be exacerbated for smaller firms, suggesting that policy on these links should attempt to ameliorate weaknesses in quality and improve access for smaller firms. The range of patterns of these interactions is very broad and likely to vary systematically across sectors. Therefore, policies need to cater to the specific requirements of different sectors. In a regional context, they need to be nested in specific regional development strategies. In the small, open economy of the United Kingdom, the tension between promoting national sector-based schemes and regional schemes requires careful management.

This brief overview of the SET policy system in the United Kingdom highlights the complexity of the system and the diversity of actual and potential intervention routes. Effective policy intervention in connection with university-industry relationships requires an overall holistic view of this policy framework. It also requires a long-term perspective, to enable a degree of predictability in the functioning of the system. The 10-year framework for investment in science and technology for 2004 to 2014

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[4] See http://www.sbri.org.uk/aboutus.php for the details.

is clearly a welcome step in providing a long-term perspective within which to work. A number of elements in the framework make a positive contribution to university-industry relationships. A central problem for the framework is the likelihood that the private sector component of the R&D target will not be met, given the structural features of R&D spending in the United Kingdom. However, the target is one of the less important aspects of the framework. Instead, those aspects that concentrate on developing the quality of university-industry relationships and the flow of knowledge to business are likely to be most fruitful in the longer run. In a review of the elements of policy that address these aspects, the underexploited potential of public procurement for small high-technology businesses stands out.

References

Connell, David. 2004. "Exploiting the U.K.'s Science and Technology Base: How to Fill the Gaping Hole in the U.K. Government Policy." TTP Ventures, Cambridge, U.K.

———. 2006. "'Secrets' of the World's Largest Seed Capital Fund: How the United States Government Uses Its Small Business Innovation Research (SBIR) Programme and Procurement Budgets to Support Small Technology Firms." Centre for Business Research, University of Cambridge, U.K.

Cosh, Andy, Alan Hughes, and Richard K. Lester. 2006. *U.K. plc: Just How Innovative Are We?* Cambridge, U.K.: Cambridge-MIT Institute.

Cox, George. 2005. *Cox Review of Creativity in Business: Building on the U.K.'s Strengths*. London: Her Majesty's Stationery Office.

Cox, Mark, Alan Hughes, and Rod Spires. 2002. *Evaluation of SMART (Including SPUR) 2001: Final Report and Appendices*. DTI Evaluation Report 3. Sheffield, U.K.: Small Business Service. http://www.dti.gov.uk/files/file22000.pdf.

DTI (Department of Trade and Industry). 2003. "Competing in the Global Economy: The Innovation Challenge." DTI Innovation Report, Her Majesty's Stationery Office, London.

———. 2005. "R&D-Intensive Businesses in the U.K." DTI Economics Paper 11, DTI, London.

HEFCE (Higher Education Funding Council for England). 2003a. *Review of Research Assessment: Report by Sir Gareth Roberts to the UK Funding Bodies*. London: Higher Education Funding Council for England, Higher Education Funding Council for Wales, Scottish Higher Education Funding Council, and Department for Employment and Learning. http://www.ra-review.ac.uk/.

———. 2003b. "Statement by the UK Higher Education Funding Bodies on the Review of Research Assessment." News release, HEFCE, London. http://www.hefce.ac.uk/news/hefce/2003/review_ra.asp.

Her Majesty's Treasury. 2003. *Lambert Review of Business-University Collaboration: Final Report*. London: Her Majesty's Stationery Office.

Her Majesty's Treasury, DTI (Department of Trade and Industry), and DfES (Department for Education and Skills). 2004. *Science and Innovation Investment Framework, 2004–14*. London: Her Majesty's Stationery Office.

Her Majesty's Treasury, DTI (Department of Trade and Industry), DfES (Department for Education and Skills), and DOH (Department of Health). 2006. *Science and Innovation Investment Framework, 2004–14: Next Steps*. London: Her Majesty's Stationery Office.

Hughes, Alan. 2003. "Knowledge Transfer, Entrepreneurship, and Economic Growth: Some Reflections and Policy Implications." In *Entrepreneurship in the Netherlands—Knowledge Transfer: Developing High-Tech Ventures*, 53–75. The Hague: EIM Business Policy and the Netherlands Ministry of Economic Affairs.

Lester, Richard K. 2005. "LIS Project—Phase I Findings: Overview and Discussion." MIT IPC Local Innovation Systems Working Paper 05-004, Industrial Performance Center, Massachusetts Institute of Technology, Cambridge, MA.

Lester, Richard K., and Michael J. Piore. 2004. *Innovation—The Missing Dimension*. Cambridge, MA: Harvard University Press.

Marshall, Alfred. 1923. *Industry and Trade: A Study of Industrial Technique and Business Organization, and Their Influences on the Conditions of the Various Classes and Nations*. 4th ed. London: Macmillan.

SQW Limited. 2002. *Evaluation of Teaching Company Scheme (TCS): Executive Summary and Main Report*. DTI Evaluation Report 7, Cambridge, U.K.: SQW Limited.

TSB (Technology Strategy Board). 2006. "Technology Strategy: A Call to Action." TSB, London.

CHAPTER 5

Universities and Public Research Institutions as Drivers of Economic Development in Asia

John A. Mathews and Mei-Chih Hu

The East Asian experience with catch-up industrial development, achieved over the half-century from 1950 to 2000, stands as one of the great episodes of modern economic development. The mechanisms that were used to steer the development of industries and markets, involving states and state-sponsored institutions working closely with private firms and markets, have stirred one of the greatest controversies of the modern social sciences. On one side stand the neoclassical economists with their deductive approach to understanding industrial development, establishing the models first and then trying to fit the models to the reality. On the other side stand the revisionists, starting with the empirical facts and trying to develop frameworks that accommodate both the facts and the policies pursued. Those debates have now spilled over, both historically and intellectually, into the current encounter with China and India, the two towering success stories of globalization, modernization, and industrial development that promise so much in the 21st century.

In this grand intellectual theater, the role of technological capacity development is coming to be viewed as central to the industrialization effort—and as the driving factor in East Asian success over the past half century.[1] In this setting, universities and public research institutes (PRIs) are two of the key institutions that shape economic development.

In a nutshell, the argument presented here is that universities played a very special role in East Asian development—not as drivers of innovation, as commonly viewed in the West, but as shapers of human capital formation. Throughout this half-century, universities were at the forefront in training generation after generation of highly skilled, technologically sophisticated graduates, who could be employed successfully by domestic firms seeking to enter global industries, by multinational corporations, and not least by the institutions steering the economy's industrial development. The foundation for this role played by the universities and newly established polytechnics was the steadily rising rate of adult literacy and numeracy, which by 2000 was approaching 100 percent in countries such as the Republic of Korea—among the highest in the world.

By contrast, the PRIs, such as the Industrial Technology Research Institute (ITRI) in Taiwan (China), played the role of technology capture agencies and technology diffusion managers, going abroad to seek the technologies needed by local firms and building capabilities in those technologies, which the PRIs then passed across to the private sector as rapidly as possible. These institutes worked closely with domestic firms (even establishing firms where they were lacking), catalyzing their capacities to become technologically sophisticated players in their own right. PRIs drove the development of national innovative capacity in East Asian economies, as they gradually moved from catching up and imitation to fast-follower innovation.

In the opening years of the 21st century, both universities and PRIs in East Asia are undergoing further transformation, as the effects of Bayh-Dole-type policies are felt. Thus, economies as diverse as Hong Kong (China), Singapore, and Taiwan (China) are pursuing similar strategies: universities and PRIs are encouraged to keep abreast of new technologies by patenting, by publishing in scientific journals, and by promoting spinoff enterprises. Although the results are still rudimentary at this stage, they point to a trend that could become significant in the near future, particularly as it is adopted and expanded in China and India.

[1] See Amsden and Chu (2002), Kim (1997), Lall (1997), or Lall and Urata (2002) for representative discussions. Cardozo (1999) provides a useful summary of the arguments.

This chapter offers an overview of these tendencies, both retrospectively, on the role of universities and PRIs in East Asia over the past half-century, and prospectively, on the current trend toward playing a more catalytic role in sparking new technological directions for the economies concerned. The chapter draws on a decade and more of intensive study of the East Asian industrialization phenomenon.[2]

The Latecomer Development Model

From 1950 to 2000, the East Asian economies fashioned a uniquely successful industrial development model in which the focus was clearly on "science and technology as the primary productive forces," to quote a famous phrase of Chinese leader Deng Xiaoping. The idea was that these economies, as latecomers, could focus their industrial development on targeted catch-up efforts, industry by industry and technology by technology, drawing on the knowledge accumulated in the leading countries. The model was developed first in Japan, then rapidly adopted in Korea and Taiwan (China), and later taken up by Singapore and to some extent elsewhere in Southeast Asia.

This model was a 20th century version of the catch-up strategies that had been perfected in the 19th century by European latecomer nations, particularly Germany, and by the United States—as described so effectively by Gerschenkron (1962, 1970) in one of the most famous and decisive social science interventions of the 20th century.

The Gerschenkronian approach invites concentration on the issues that matter most, namely the building of new institutions and the pursuit of fresh strategies, depending on the situation when a country is attempting (or reattempting) its development push. Which institutions are most relevant in any given country or at any given time will vary. But the strategic use of institutions to overcome latecomer disadvantages can have a significant effect on development. With each successive entry by a latecomer country into the ranks of the industrial world, the barriers to entry change, and a different situation is bequeathed to those coming after. They must devise fresh strategies to get around the newly created barriers. Institutions and practices must then be discarded as soon as they have outlived their utility, to avoid the trap of allowing firms to become dependent on them.[3]

[2] For representative studies by this author, see Mathews (2001, 2002a, 2002b, 2003, 2005a, 2005b, 2006a, 2006b, 2006c) and Mathews and Cho (2000).

[3] See Hausmann and Rodrik (2003) or Rodrik (2004) for exemplary discussions of this essential point.

Latecomer firms, like latecomer nations, exploit their late arrival to tap into advanced technologies, rather than replicating the entire preceding technological trajectory. They can accelerate their uptake and learning efforts through collaborative processes and the help of state agencies, thereby avoiding some of the organizational inertia that holds back their more established competitors. They thus develop strategy on the basis of the possibilities inherent in their latecomer status. The strategic goal of the latecomer is clear: it is to catch up with the advanced firms and to move as quickly as possible from imitation to innovation. This strategy has never been put into practice more effectively than by the East Asian economies in their half-century of accelerated industrial development.

The process of industrial development in East Asia may be viewed as one involving a series of choices, all conceived as strategic exercises in collective entrepreneurship. Entrepreneurship provides the appropriate framework for assessing development strategy, with an appropriate balance between the collective and individual facets of development.[4] Latecomers seek to compensate for their shortcomings in technology and market sophistication through institutional innovation, under the guidance of development agencies, creating institutional solutions as problems are encountered. Examples include using export processing zones to promote foreign direct investment in manufacturing activities and using PRIs, such as ITRI in Taiwan (China), to act as technology leveragers and builders of national technological competences. Repeated applications of the processes of linking with commercial structures and leveraging knowledge from such sources teach latecomers to practice development as a process of collective entrepreneurship. Figure 5.1 displays the institutions used in East Asia over the decades of its catch-up efforts, covering such specific matters as technology capture and diffusion, financial attraction, and new industry creation.[5]

The Role of Universities and PRIs in Industrial Development in East Asia, 1950–2000

In keeping with the latecomer strategy, the East Asian economies never saw universities as agents of innovation, at least not during their half-century of accelerated catching up. Rather they saw universities as agents

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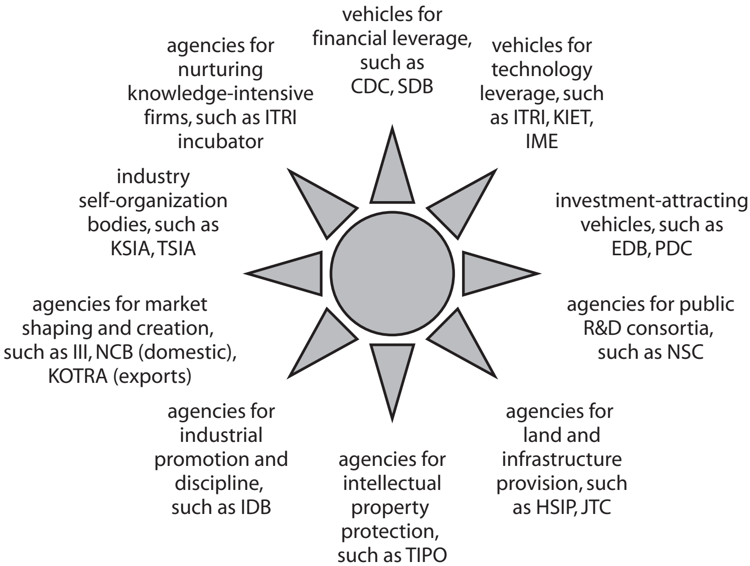
[4] On collective entrepreneurship as a setting for development strategies, see Leibenstein (1968).

[5] For exposition, see Mathews (2006a, 2006c) and Mathews and Hu (forthcoming).

Figure 5.1. National Systems of Economic Learning in East Asia



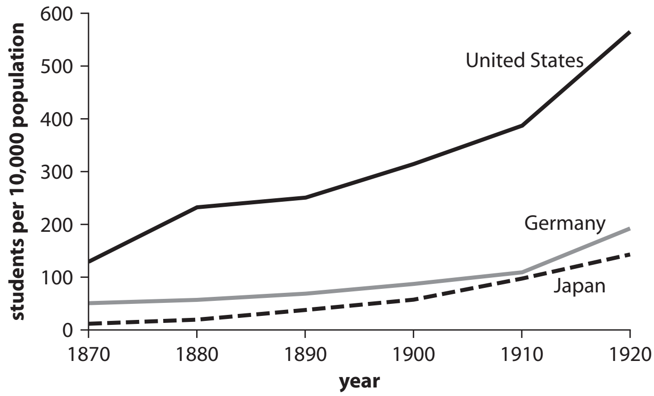
Source: Mathews and Cho 2000.

Note: CDC = China Development Corporation; EDB = Economic Development Board (Singapore); HSIP = Hsinchu Science-Based Industrial Park; IDB = Industrial Development Bureau (Taiwan, China); III = Institute for Information Industry (Taiwan, China); IME = Institute for Microelectronics (Singapore); ITRI = Industrial Technology Research Institute; JTC = Jurong Town Corporation (Singapore); KIET = Korea Institute of Electronic Technology; KOTRA = Korea Overseas Trade Promotion Agency (renamed Korea Trade Investment Promotion Agency in 1995); KSIA = Korea Semiconductor Industry Association; NCB = National Computer Board (Singapore); NSC = National Science Council (Taiwan, China); PDC = Penang Development Corporation (Malaysia); SDB = Singapore Development Bank; TIPO = Taiwan Intellectual Property Office; TSIA = Taiwan Semiconductor Industry Association.

of human capital formation; universities were viewed as advanced training institutions and were built and established at an enormous rate. In Taiwan (China), for example, the economy's technical education superstructure expanded rapidly in parallel with other efforts to tap the knowledge of the advanced countries. In 1952, there were four universities and four junior colleges, with total enrollment of 10,037 students; of these, 2,590 studied engineering. By 1989, this infrastructure had expanded to 42 universities and 75 polytechnics or colleges, a massive expansion in just over three decades. Many of the institutions, such as the National Chiao Tung University and the National Tsinghua University, were actually carried over from their mainland origins and today stand at the pinnacle of the tertiary education system in Taiwan (China).

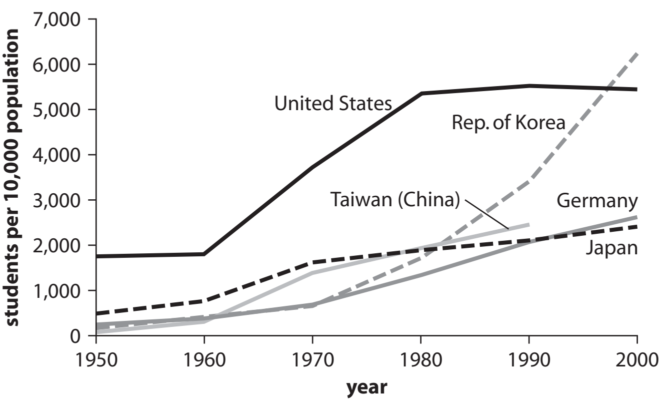
Likewise, the Republic of Korea poured resources into the tertiary sector, so much so that by the turn of the century its levels of enrollment were higher than those for the United States, which had been the leader in human capital formation for the preceding century (figures 5.2 and 5.3). Figure 5.2 shows how the latecomer countries in the 19th century had likewise poured resources into tertiary institutions as the foundation for their catch-up strategy. Figure 5.4 drives home the point that latecomers that specialize in science and engineering first degrees stand the best chance of raising their per capita GDP.

Figure 5.2. University Students per 10,000 Population, 1870–1920



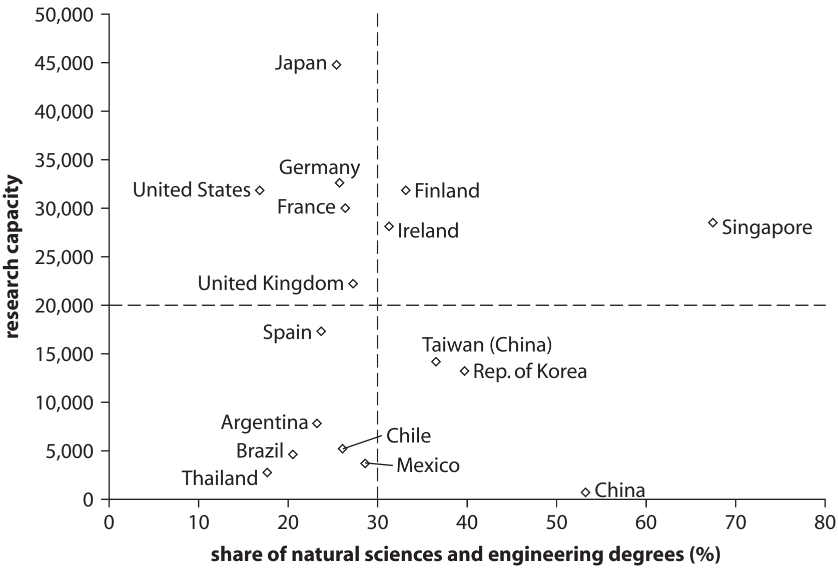
Source: Provided to authors by the United Nations Industrial Development Organization.

Figure 5.3. University Students per 10,000 Population, 1950–2000



Source: Provided to authors by the United Nations Industrial Development Organization.

Figure 5.4. GDP per Capita versus Share of Natural Sciences and Engineering Degrees, 2000 or Most Recent Year



Source: Provided to authors by the United Nations Industrial Development Organization.

The Role of PRIs

Although universities played the role of human capital formation institutions, the actual tasks of leveraging technology and diffusing it to the private sector were allocated to PRIs. They emerged as the central and defining institutions of the East Asian catch-up experience.

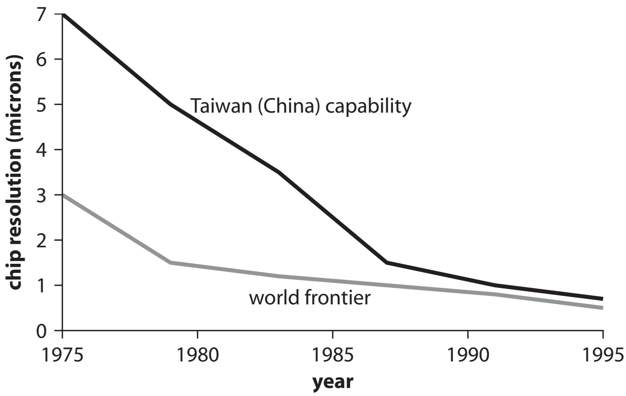
ITRI of Taiwan (China), founded in 1973, serves as the benchmark for such technology capture and diffusion institutions. It was the prime agency in building pilot versions of new technologies before they were taken up by the private sector. It did not engage in fundamental scientific research; on the contrary, it was concerned strictly with identifying and evaluating available technologies. ITRI provided shared research and development (R&D) services for existing and emerging industries, precisely as the R&D department of a large, established company does. Technologies already being used are tested to see how they can be improved; technologies used by rivals and competitors are reconstructed and analyzed; potential substitute technologies are evaluated. These are the activities of an R&D department in a large firm such as International Business Machines (IBM) or Toshiba, and they are the means by which the company builds its technological absorptive capacity. But in a latecomer economy, few firms can afford such a department. If they can, they can make the technical evaluations of new projects for themselves or they can hire expensive consultants to do so for them. Although most firms have no means to benefit from such services, such services are needed to enable the economy to capture its potential latecomer advantages. ITRI was the general institution that filled that gap in Taiwan (China).

Of many possible examples, consider how Taiwan (China) became a player in the semiconductor industry in the 1980s through the targeted efforts of ITRI. The first semiconductor capabilities in Taiwan (China) were acquired by ITRI. One of its laboratories entered into a technology-transfer agreement with the U.S. firm, RCA, in 1976, thereby acquiring initial capabilities in semiconductor fabrication and design. RCA considered the technology transferred obsolete, but it served as a training ground for ITRI, which then spread the skills to the private sector by spinning off a new company, United Microelectronics Corporation (UMC), in 1980. UMC has repeatedly entered into new alliances with advanced firms, bringing itself up to world-class technological levels.

In 1986, ITRI entered into a technology-transfer agreement with the European multinational Philips, to form a new VLSI (very-large-scale integration) spinoff, giving Philips new fabrication capacity and privileged access to the Taiwan (China) market. To avoid competing directly with Philips, this new company—Taiwan Semiconductor Manufacturing Corporation (TSMC)—elected to produce chips only for third parties, thereby inventing the concept of the silicon foundry. This concept has proven to be remarkably successful, and TSMC has continuously enlarged and deepened its technological capacities by assimilating the technological specifications of its customer firms as it takes orders to produce their chips.

By the late 1990s, firms in Taiwan (China) were closing the gap between their technological capabilities and the world frontier. This key strategic goal of the latecomer dominated the thinking in Taiwan (China) throughout the creation of the various sectors of the electronics industry. In particular, in semiconductors, the state of technological sophistication can be captured in terms of the line widths used in etching circuits onto the silicon substrate, as shown in figure 5.5. In the initial technology transfer from RCA in 1977, the line widths were 7 microns. This line width had been reduced to 2 microns by 1985, when the world frontier

Figure 5.5. Taiwan (China) Closes the Gap in Semiconductors, 1975–95



Source: Mathews and Cho 2000; provided to the authors by the Electronics Research and Service Organization.

was at just over 1 micron—and in 1995, the firms in Taiwan (China) had just about caught up, with submicron technology comparable to that used in the world's leading firms. Such technology gaps must be tracked obsessively by latecomers that are engaged in catching up—as they were by Taiwan (China) in catching up in electronics.[6]

This analysis examines these issues through the lens of the development of national innovative capacity in East Asian economies. As documented in the expanding literature, universities and PRIs such as ITRI may be seen as contributing not only to their own innovation results but more fundamentally to the economy's innovative capacity—that is, capacity to sustain and enhance innovation as the industrial structure becomes more knowledge based.[7] Recent reforms in East Asian economies such as Hong Kong (China), Singapore, and Taiwan (China) are calculated to promote academic innovation through institutional and organizational reforms and thus to drive the transition from manufacturing fast follower to innovation-based technology developer.[8]

6 For an exposition of this experience, see Mathews and Cho (2000).

7 On national innovative capacity, see contributions such as Hu and Mathews (2005) and Suarez-Villa (1990).

8 For an overview of recent work on industry-science links and the role of universities in promoting technological initiatives, see Link and Siegel (2005).

From Imitation to Innovation

One of the clearest indications of innovation performance is the rate of take-up of patents issued by the U.S. Patent and Trademark Office (USPTO).[9] Recent studies have looked at linking the rate of patenting with economic variables such as R&D expenditure and the proportion of scientists and technologists employed in a sector or economy. Such studies find that East Asian firms and institutions have made astonishing strides in recent years. Taiwan (China), in particular, has risen to third highest in the world in terms of per capita uptake of USPTO patents between 1997 and 2001 (table 5.1).

Table 5.1 shows the experience of East Asia in patenting with the USPTO, as compared with the experience of Group of Seven (G7) countries and that of a reference group including Finland and Israel. The table reveals the rapid rise of East Asia as an innovative force. In terms of utility patents taken out in the United States over the past five years, per capita, Taiwan (China) ranks third behind the United States and Japan. Korea ranks eighth, with 6.6 patents per capita per year, averaged over the past five years, while Singapore is rising fast at eleventh on a per capita basis. China has few USPTO patents as yet.[10]

If we look at the firms and institutions involved, we gain a clearer idea of what has been happening in these latecomer countries. Table 5.2 shows the number of patents taken out each year from 1997 to 2001 by East Asian organizations (both firms and institutions). Almost all of these firms and organizations operate in the electronics, information technology, communications, and particularly semiconductor sectors. These advanced sectors in which the East Asian firms have been making their mark are driving the overall totals reported in table 5.2.

Korea has been more focused and concentrated in its patenting activities than other East Asian economies. In Korea, the top five *chaebol* account for a large proportion of patents overall (69.0 percent) from 1997 to 2001, whereas in Taiwan (China), the top five firms and organizations,

[9] The USPTO is itself a product of American catch-up efforts. It was the first government agency established by the federal government in the 18th century, and its charter is embedded in the U.S. Constitution.

[10] See Hu and Mathews (2005) for an analysis of the patenting performance of five East Asian economies in terms of their uptake of patents from the USPTO. This methodology is expected to be applied to more and more developing countries, starting with China and India, and also to middle-ranking but highly innovative countries such as Finland, Ireland, and Israel, as well as countries in Central and Eastern Europe, Central and South America, Australasia, and (eventually) Africa.

Table 5.1. Country Patenting Performance for 5- and 30-Year Periods

	Number of patents per year			*Number of patents per capita*			*Success rate (%)*			*Annual growth rate (%)*		
Country	*1968–97*	*1992–97*	*1997–2001*	*1968–97*	*1992–97*	*1997–2001*	*1968–97*	*1992–97*	*1997–2001*	*1968–97*	*1992–97*	*1997–2001*
G7 countries												
Canada	1,380	2,119	3,121	4.9	7.2	10.2	50.7	49.3	48.6	6.5	7.5	11.2
France	2,432	2,881	3,662	4.3	5.0	6.2	66.5	61.9	60.4	16.4	3.7	8.5
Germany	5,806	6,895	9,387	9.2	8.4	11.4	59.5	59.8	59.3	2.7	4.3	13.0
Italy	855	1,215	1,548	1.7	2.1	2.7	54.1	58.3	61.5	4.4	4.5	9.2
Japan	11,216	22,433	29,949	10.3	17.9	23.7	55.5	57.9	61.5	8.6	6.5	10.2
United Kingdom	2,492	2,427	3,469	4.0	4.2	5.9	53.5	50.2	50.6	2.7	6.7	10.8
United States	44,850	56,683	79,717	15.5	21.5	28.6	58.9	52.2	53.2	4.9	7.9	9.7
Other countries												
Finland	181	370	609	4.2	7.2	11.8	48.6	51.3	47.0	11.4	10.0	13.6
Israel	183	400	757	4.2	7.2	12.4	42.2	40.5	37.1	12.5	15.4	17.3
East Asian economies												
Hong Kong (China)	31	72	162	0.6	1.2	2.3	40.3	38.7	42.6	14.2	23.0	35.6
Korea, Rep. of	267	1,134	3,113	0.7	2.5	6.6	37.3	39.0	56.1	39.1	36.1	20.4
Singapore	16	59	174	0.6	1.7	4.4	40.2	41.5	33.3	44.9	26.2	33.7
Taiwan (China)	437	1,535	3,778	2.3	7.3	17.2	35.5	39.3	45.7	26.2	21.4	27.8

Source: Provided to authors by USPTO; World Development Indicators database 2003.

Note: Data are for utility patents only. Data for Germany before 1990 include only patents in the Federal Republic of Germany.

Table 5.2. The 10-Year Science and Innovation Investment Framework R&D Target

	Number of patents					
Country and firms	*1997*	*1998*	*1999*	*2000*	*2001*	*Total 1997–2001*
China						
World Semiconductor Manufacturing Corp.	0	0.3	6	61	37	104
Republic of Korea						
Samsung Electronics	584	1,305	1,545	1,441	1,450	6,325
Hyundai Electronics	154	212	242	294	533	1,435
LG Electronics	113	215	229	220	248	1,025
Daewoo Electronics	215	319	273	120	54	981
LG Semiconductors	119	235	311	255	42	962
Electronics and Telecommunications Research Institute	58	120	130	124	72	504
Korea Institute of Science and Technology	29	44	41	35	35	184
Singapore						
Chartered	30	39	44	79	135	327
Taiwan (China)						
United Microelectronics Corp.	149	174	266	430	584	1,603
Taiwan Semiconductor Manufacturing Corp.	130	218	290	385	529	1,552
ITRI	153	218	208	198	221	998
Vanguard International Semiconductor Corp.	53	120	112	131	112	528
Winbond	24	59	115	115	126	439
Mosel-Vitelic	15	32	38	66	68	219

Source: Her Majesty's Treasury, DTI, and DfES 2004.

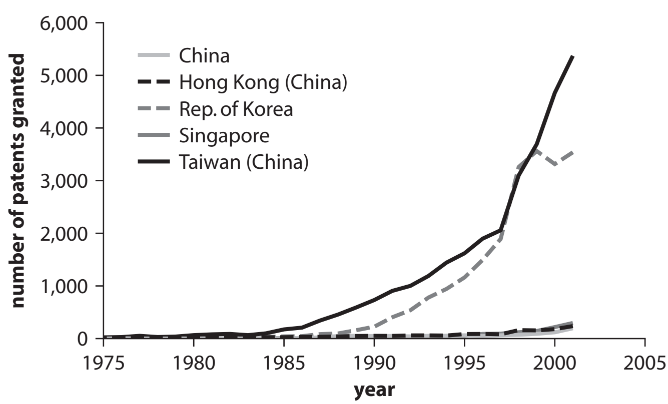
all from the semiconductor sector, account for a smaller proportion overall (27.1 percent). Patterns established in the realm of production appear to be carried across to the sphere of innovation. Thus, we may argue on the basis of this prima facie evidence that East Asian economies, led by Taiwan (China) and Korea, have developed the institutional foundations of national innovation capacity—and that they are actively developing these foundations as part of their strategy to move beyond imitation to innovation (Kim 1997), as Japan has.

Innovative capacity is the basic driving force behind economic performance; it provides a measure of the institutional structures and support systems that sustain innovative activity. National innovative capacity may be broadly defined as the institutional potential of a country to sustain innovation. It has been investigated by numerous scholars, at least since 1990, when Suarez-Villa formulated a clear definition of the concept and a measure of it in terms of patenting rates. The notion can be applied at regional and other subnational levels (Neely and Hii 1999). Thus, the capacity to innovate is concerned with no single aspect of innovation performance, but rather with the sources of its sustainability.

In a new study, Hu and Mathews (2005) extend and modify earlier approaches by applying them to five latecomer economies in East Asia, none of which was included in the Furman, Porter, and Stern (2002) study, and in particular to Taiwan (China). Hu and Mathews document some important differences for these economies: a smaller number of national factors matter, and there seems to be an important (though subtle) role for public R&D expenditure. These findings have important implications for successful catch-up strategies. These aggregate findings are supplemented with firm- and institution-level data from Taiwan (China), where the breakthrough to innovation has arguably proceeded further than in any other East Asian economy.

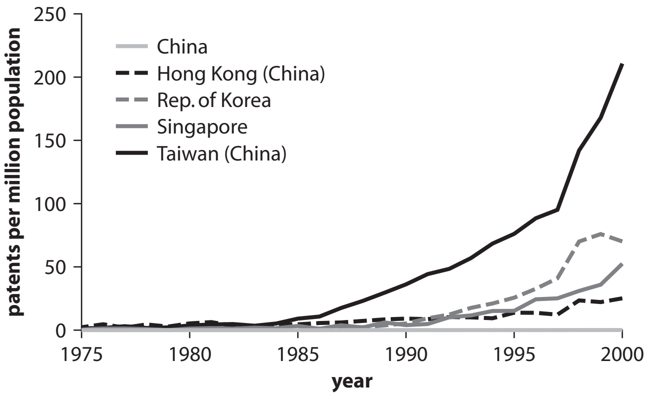
Data for patents granted in East Asian tiger economies are shown in figures 5.6 and 5.7. Korea and Taiwan (China) have been rapidly increasing their patenting rates, with Taiwan (China) pulling away in per capita terms. The proposition that these economies are moving closer to the innovation frontier is further strengthened when examining predicted

Figure 5.6. Patents Granted, 1975–2002



Source: Hu and Mathews 2005.

Figure 5.7. Patents Granted, per Million Population, 1975–2000



Source: Hu and Mathews 2005.

patenting rates based on innovation capacity (Hu and Mathews 2005), which show that once again Taiwan (China) has pulled away from the other East Asian economies.

The innovative capacities of Taiwan (China) may thus be viewed as moving beyond the stage in which the PRIs, led by ITRI, laid down the main lines of industrial development and, through various forms of technology diffusion management, induced the private sector to follow. Taiwan (China) is moving beyond the institutional forms of this early model of fast followership toward greater variety in institutional mixes and strategies, offering universities a more direct role. Its approach exemplifies that pursued in East Asia generally.

The Emerging Role of Universities and PRIs in East Asia

The story in East Asia may be brought up to the 21st century by focusing on the new policies being pursued. These policies were inspired by the Bayh-Dole Act of 1980 in the United States, which set a new benchmark for universities and PRIs around the world.[11] The basic effect of the Bayh-Dole Act was to provide an incentive for universities and PRIs in the United States to take possession of intellectual property rights (IPRs). Recognizing the profound effect that the act has had in

[11] However, see Branscomb, Kodama, and Florida (1999) for a fascinating comparison of university-industry links in Japan and the United States.

the United States, other countries—particularly those in East Asia—have been quick to follow suit. Korea, Singapore, and Taiwan (China), and now China and India, are all promoting their universities and PRIs as champions of a new style of innovation driven by patenting, publishing in key scientific and technical journals, and spinning off new enterprises. But this institutional innovation is a latecomer; the new entrepreneurial activities remain targeted to key industries and technologies.

Many Asian economies, such as Japan, Korea, and Taiwan (China), have sought to endow their universities and PRIs with greater capacity to benefit from their own intellectual property generation initiatives. In this spirit, for example, the Taiwan (China) government (the Executive Yuan), in 1999 laid down a basic law on science and technology that reorganized the management of IPRs in public institutions in approximately the same manner as the Bayh-Dole Act. For those IPRs and achievements of science and technology R&D that are funded and subsidized by the government, all or part will be given to or authorized for use by research institutes or enterprises. They will not be constrained by the national property law.

Table 5.3 shows the effect of these new policies, in terms of licenses awarded by universities and licensing revenues achieved by universities. The number of technology licensing agreements leapt to 1,341 in 2004, up from only 40 in 2001; licensing revenues also increased dramatically, to reach NT$137.9 million (approximately US$4.6 million) in 2004. The number of patents awarded through the National Science Council (NSC) does not show the same dramatic increases—but this finding probably reflects the reality that many patents are being taken out by university faculty outside the NSC system, in addition to those represented in the table 5.3.

Table 5.3. Technology-Transfer Outcomes in Taiwan (China) under the National Science Council, 2000–04

Type of outcome	*Before 1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*
Number of technology licenses	124	25	44	40	492	933	1,341
Technology licensing revenue (NT$ million)	38.1	15.6	32.5	49.9	54.3	122.0	137.9
Number patents awarded	985	171	288	271	222	137	—
(foreign patents)	(408)	(86)	(117)	(97)	(83)	(34)	—

Source: National Science Council, http://www.nsc.gov.tw.

Note: — = not available.

Table 5.4. Top Five Patenting Technologies in Taiwan (China) Supported by the National Science Council

Technology	*Number of patents*
Optoelectronics	253
Chemicals	204
Chemical engineering	201
Materials	137
Electrical engineering	133

Source: National Science Council, http://www.nsc.gov.tw.

Note: Technology is categorized on the basis of patents granted in the Taiwan Intellectual Property Office, USPTO, Japan Patent Office, and European Patent Office.

Table 5.4 shows the industrial specialization of patents awarded under the NSC scheme. It reveals the strategic significance of new sectors such as optoelectronics and electrical engineering, as well as core upstream technologies in chemical engineering and materials that feed into numerous downstream industries. This distribution reveals that the NSC policies are successful in keeping the R&D output of universities and PRIs in close accord with the economy's strategic industrial directions as a latecomer.

A small economy such as that of Taiwan (China) cannot hope to develop evenly across all industrial sectors. But, as we have seen, through judicious policies it can specialize and build its capabilities to the world frontier in certain sectors. The NSC funding is targeted in a way that clearly extends this sectoral specialization from production activities to innovation activities. But note the striking absences in table 5.4—namely, semiconductor and electronics patenting. These sectors are now mature, and most of the patenting is being undertaken by the leading firms—such as TSMC and UMC—as well as ITRI; the NSC has not attempted to duplicate what these institutions are already doing well.

Although the role of universities in R&D is aimed at generating ideas and innovation, that of the PRIs such as ITRI is focused on fostering innovative activity and new ventures. ITRI has been well known as the technology pivot of Taiwan (China), and the technology licensing offices in National Taiwan University, National Chiao Tung University, and National Tsinghua University, under their grants from the NSC, are performing well.[12]

[12] These three cases are studied by Mathews and Hu (forthcoming).

Generalizability of the East Asian Experience

Of all the countries in the developing world today, China and, to some extent, India, appear to be the most successful at applying the lessons of technology leverage. They are drawing on the accumulated stock of knowledge of the industrial world and applying it in accelerated fashion to their development agendas. China, in particular, appears to have studied the model of Taiwan (China) very closely and, despite political differences, is applying it very successfully to its own case in sector after sector: in electronics and semiconductors, as well as in aerospace, advanced machine tools, and other knowledge-intensive industries.

Of course, the East Asian models need to be updated, as discussed at some length in recent World Bank studies.[13] The principal difference between the world faced by East Asian countries in the 1960s and the world faced today by latecomers such as Latin American or Central Asian countries is the tight regulation by the World Trade Organization (WTO) and its associated instruments, such as the TRIPS (Trade-Related Aspects of Intellectual Property Rights) agreement and the TRIMS (Trade-Related Investment Measures) agreement, which deals with investment-related policies such as local content regulations. Discussions of the prospects for developing countries are concerned with the barriers created by such WTO instruments.

Nevertheless, the experience of East Asian economies in building technological capacities that enabled them to catch up with industrial countries—through technology capture and diffusion programs, programs to nurture new firms, and programs focused on seeding new industry—remains a standard for what can be achieved by latecomer countries without breaching any WTO, TRIPS, or TRIMS protocols. As those economies catch up and approach the technological frontier alongside the industrial countries, they can modify the institutional parameters of their universities and PRIs to enable them to play a more entrepreneurial role in driving new technological developments. It is a case of taking one step at a time and not attempting to run (with a Silicon Valley–style model) before learning how to walk (with an imitation-driven innovation system). This is the enduring lesson of the latecomer effect in industrial development.

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[13] Yusuf (2003) is concerned with the capacity of East Asia's economies to move from the imitation practices that have worked so well in the past toward a more open system of innovation. See also World Bank (2003).

References

Amsden, Alice H. and Wan-wen Chu. 2002. *Beyond Late Development: Taiwan's Upgrading Policies*. Cambridge, MA: MIT Press.

Branscomb, Lewis M., Fumio Kodama, and Richard Florida, eds. 1999. *Industrializing Knowledge: University-Industry Linkages in Japan and the United States*. Cambridge, MA: MIT Press.

Cardozo, Guillermo. 1999. "Learning and Innovation Paths in East Asia." *Science and Public Policy* 26 (4): 259–76.

Furman, Jeffrey L., Michael E. Porter, and Scott Stern. 2002. "The Determinants of National Innovative Capacity." *Research Policy* 31: 899–933.

Gerschenkron, Alexander. 1962. *Economic Backwardness in Historical Perspective*. Cambridge, MA: Belknap Press.

———. 1970. *Europe in the Russian Mirror*. Cambridge, MA: Belknap Press.

Hausmann, Ricardo, and Dani Rodrik. 2003. "Economic Development as Self-Discovery." *Journal of Development Economics* 72 (2): 603–33.

Her Majesty's Treasury. 2003. *Lambert Review of Business-University Collaboration: Final Report*. London: Her Majesty's Stationery Office.

Her Majesty's Treasury, DTI (Department of Trade and Industry), and DfES (Department for Education and Skills). 2004. *Science and Innovation Investment Framework, 2004–14*. London: Her Majesty's Stationery Office.

Hu, Mei-Chih, and John A. Mathews. 2005. "Innovative Capacity in East Asia." *Research Policy* 34 (9): 1322–49.

Kim, Linsu. 1997. *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Cambridge, MA: Harvard Business School Press.

Lall, Sanjaya. 1997. *Learning to Industrialize: The Acquisition of Technological Capability by India*. London: Macmillan.

Lall, Sanjaya, and Shujiro Urata, eds. 2002. *Competitiveness, FDI, and Technological Activity in East Asia*. Cheltenham, U.K.: Edward Elgar.

Leibenstein, Harvey. 1968. "Entrepreneurship and Development." *American Economic Review* 58 (2): 72–83.

Link, Albert N., and Donald S. Siegel. 2005. "University-Based Technology Initiatives: Quantitative and Qualitative Evidence." *Research Policy* 34 (3): 253–57.

Mathews, John A. 2001. "National Systems of Economic Learning: The Case of Technology Diffusion Management in East Asia." *International Journal of Technology Management* 22: 455–79.

———. 2002a. "Competitive Advantages of the Latecomer Firm: A Resource-Based Account of Industrial Catch-Up Strategies." *Asia Pacific Journal of Management* 19: 467–88.

———. 2002b. "The Origins and Dynamics of Taiwan's R&D Consortia." *Research Policy* 31 (4): 633–51.

———. 2003. "Competitive Dynamics and Economic Learning: An Extended Resource-Based View." *Industrial and Corporate Change* 12: 115–45.

———. 2005a. "The Intellectual Roots of Latecomer Industrial Development." *International Journal of Technology and Globalisation* 1 (3–4): 433–50.

———. 2005b. "Strategy and the Crystal Cycle." *California Management Review* 47 (2): 6–32.

———. 2006a. "Catch-Up Strategies and the Latecomer Effect in Industrial Development." *New Political Economy* 11 (3): 313–35.

———. 2006b. "Dragon Multinationals: New Players in 21st Century Globalization." *Asia Pacific Journal of Management* 23: 5–27.

———. 2006c. "Electronics in Taiwan—A Case of Technological Learning." In *Technology Adaptation and Exports: How Some Countries Got It Right*, ed. Vandana Chandra, 83–126. Washington, DC: World Bank.

Mathews, John A., and Dong-Sung Cho. 2000. *Tiger Technology: The Creation of a Semiconductor Industry in East Asia*. Cambridge, U.K.: Cambridge University Press.

Mathews, John A., and Mei-Chih Hu. Forthcoming. "Enhancing the Role of Universities in Building National Innovative Capacity in East Asia: The Case of Taiwan." *World Development*.

Neely, Andy, and Jasper Hii. 1999. "The Innovative Capacity of Firms." Report commissioned by the Government Office for the East of England, Center for Business Performance, Judge Institute of Management Studies, University of Cambridge, U.K.

Rodrik, Dani. 2004. "Development Strategies for the 21st Century." In *New Development Strategies: Beyond the Washington Consensus*, ed. Akira Kohsaka, 13–38. Basingstoke, U.K., and New York: Palgrave Macmillan.

Suarez-Villa, Luis. 1990. "Invention, Inventive Learning, and Innovative Capacity." *Behavioral Science* 35 (4): 290–310.

World Bank. 2003. *East Asia Integrates: A Trade Policy Agenda for Shared Growth*. Washington, DC: World Bank.

Yusuf, Shahid. 2003. *Innovative East Asia*. New York: Oxford University Press.

CHAPTER 6

UIL-Related Policies of National Governments

A Synthetic View

Rémi Barré

University-industry links (UILs) generate a range of complementary externalities between university and industry systems and are thus a major determinant of the efficiency of national innovation systems. The production of such externalities and their internalization by industry can be viewed as one of the raisons d'être of academic research, hence the importance of having proper policies regarding such links.

The chapters in this volume address national policies from two perspectives: a microanalytical view and a macrosystemic view.

Starting from the Microanalytical View: UILs in a Local but Complex Dynamic

Hughes (chapter 4) and Jiang, Harayama, and Abe (chapter 8) propose a thorough review of the variety of mechanisms and processes linking universities and firms. Both chapters emphasize aspects such as spinoffs and start-ups, intellectual property management, links with the local "industrial ecosystem," and the support of small and medium enterprises (SMEs). This approach leads to the notion of an entrepreneurial university, a notion that expresses the fact that the identity of universities, as well as their governance, is in question when UILs are placed at the center of attention. The inherent tension between this so-called third mission component and the two research and teaching components is further addressed by Foray (chapter 3).

In the chapters by Hughes and by Jiang, Harayama, and Abe, national policy is given due notice with the place of UILs in the successive basic plans for research in Japan and the high-level reports and policy initiatives in the United Kingdom. But interestingly, in both chapters, an emphasis is on the responsibilities of local initiatives, considered implicitly to be hardly amenable to national policy instruments. We are thus informed that Tohoku University has developed intensive UILs for decades already and that, in the United Kingdom, surveys show that UILs are heavily dependent on behavioral components, informal public space, and conventional university outputs. In other words, there is nothing mechanistic in such relations, and direct incentives are likely to have little attraction, in particular regarding relationships with SMEs. From this information, the authors of both chapters get to the point that UILs must be considered in the context of national innovation systems.

This conclusion is the starting point for the chapters by Foray (chapter 3) and Soete (chapter 2).

Starting from the Macrosystemic View: UILs as a Paradoxical Component of the National Innovation System

In the views of Foray and Soete, academic research and private research have a symbiotic relationship: firms do not innovate alone, and UILs contribute to maintaining the profitability of research and development (R&D) investment by firms. This relationship leads to a dynamic coevolution of knowledge, innovation, and institutions. Soete considers the links in the context of a national innovation system characterized by four dimensions: social and human capital, research capacity, regional clustering, and absorptive capacity. UILs are viewed ex post as a characteristic of the national system. Foray points out the importance of the indirect aspects of UILs, the objective being to optimize the complementarities between academic and industrial research through human mobility or transfer of scientific knowledge.

Both Soete and Foray argue that one must recognize the difficulties of institutionalizing direct transfer; these difficulties arise from differences in cultural norms and differences in mission (generic versus proprietary knowledge). There are reasons to believe such difficulties will increase as selectivity in academic investments leads to more academic orientation and as globalization increasingly crowds out private R&D, leading to a more even and broad geographic distribution (as in the Netherlands, for example). Here, a discrepancy appears between the national focus of academic spending, without national-level specialization, and the international focus of firms' strategies—leading to strongly differentiated and specialized territories. The missions of universities and the geographic localization of firms are strategic objectives that do not necessarily produce UILs easily.

Finally, UILs appear to be both a central part of the national innovation system and problematic, for different reasons, for each partner, hence the notion of UILs as a paradoxical component of the national system. UILs are the carriers of internal tensions within the system; these tensions make them drivers of change and, therefore, a focal point of policy.

UILs as a Driver of National Innovation Systems: The Importance of UIL Policy

In agreement with the views of Hughes and Jiang, Harayama, and Abe, Foray and Soete believe that UIL policy should be handled with care, because UILs are rooted in the local dynamics of actors. Foray raises explicitly the issue of the neutrality of UIL policy, in the sense that the policy should not discriminate among sectors or technologies. In other words, UIL policy should be strictly systemic, not thematic, so that the forces of demand and technological opportunities can play their role fully in shaping the links.

Again in agreement with Hughes and Jiang, Harayama, and Abe, Foray and Soete make a first exception, regarding relationships with SMEs, to this plea for the thematic neutrality of UIL policies. All the authors agree that the social benefit of UILs for SMEs should be considered, as should the fact that such links do not occur automatically.

A second exception, highlighted in particular by Foray, deals with coordination failures, which can prevent the emergence of new areas for UILs, in new fields or in interdisciplinary types. In such cases, thematically targeted, nonneutral UIL policies can be legitimate—and, indeed, needed—to facilitate the evolution of the national system toward adequate specialization, which natural forces would not have allowed. Such is the case of the technological top institutes in the Netherlands. In this sense, UILs act as mechanisms by which the specialization of the national innovation system evolves: the fostering of links would have policy makers focus on targeting specific (emerging) themes. Doing so would lead to an evolution in science and technology specialization, which is the rationale for the development of UILs. The assumption is that such specialization is in the best interest of both the public and the private sector.

In such a macrosystemic view, UILs are viewed as drivers of change in the national innovation system. This perspective provides proper clues about where to orient efforts to maximize both the social value of public knowledge and the production of joint knowledge that is valuable for both sides.

Observations and Questions

Foray and Soete propose a dual—micro and macro—perspective on UIL policy, stressing the central character of the issue but also the difficulties—and even the risks—of an assertive national UIL policy, which can, at best, be irrelevant and, at worst, send the wrong signals. Balancing these risks calls for particularly careful assessment of UIL policies.

Jiang, Harayama, and Abe raise the question of the smaller universities, which may have specific difficulties. Foray points out the case of universities of applied sciences. The point here is to consider the large differences between universities and the need to take those differences into account in designing policy. From the same perspective, industry links with the public research institutes should be raised as an issue. What do we know of the discrepancies between public research institutions, including universities, with regard to UILs?

To view UIL policy as an instrument for macrostrategic, thematic orientation of the national innovation system is indeed a challenging idea. Its value is to provide a backbone and reference for elaborating a macrothematic strategy. To what extent does this view represent a workable perspective? Is there not a risk of overdependence by the academic research structure on possibly transient industrial specialization and opportunities?

Finally, the main message advocated for makers of UIL policies is to be concerned primarily with framework conditions and structural characteristics and to build an enabling and facilitating environment for public and private actors to develop their strategies in a decentralized way. This approach sounds quite reasonable, but, as Soete points out, the observed increased competition in public research leads to strongly academic-oriented, fragmented research groups, all directed toward the same promising research areas. In other words, the decentralized strategies of the actors appear to lead to increasingly problematic UILs.

Soete suggests that the private sector take the lead in strengthening the links in its areas of specialization ("demand-led links") and that the public sector bring on board its own research interests, enabling the joint production of knowledge to fulfill the objectives of both sides. This approach seems promising, but can we make the policy instruments for bringing it about more explicit?

PART II

UIL-Related Policies of Subnational Governments

CHAPTER 7

The Role of Higher Education and New Forms of Governance in Economic Development

The Ontario Case

David A. Wolfe

Whereas most analyses of university-industry links focus primarily on the processes of creating and transferring knowledge from universities to industry, the university, in fact, plays a much broader role as a key institutional support for the development of local innovation systems and cluster development. A key role for government lies in strengthening the governance capacity at local and community levels so as to deploy its enabling powers more effectively to promote a process of social learning among firms and local institutions. Universities constitute one of the key institutional supports for this process. Recent experience confirms that this role is increasingly being recognized.

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In the past 15 years of rapid technological change and concerns about global competition and production, the debate on economic development has shifted. The greater emphasis on innovation reflects a better understanding of its critical role as a driver of economic growth. Region and locality have become important parts of the lexicon, in recognition of how key elements of innovative sectors, namely knowledge creation and learning, are locally influenced and rooted. More recent still is the emphasis on governance, as opposed to government. This emphasis reflects a shift in understanding toward a more flexible, multilateral process of negotiated economic development. This shift has sparked a growing interest, at both the regional and local levels, in how local communities organize to attract dynamic and innovative firms to invest in their communities, as well as in how to seed clusters. Increasingly, postsecondary research institutions are seen as critical assets to be mobilized as part of these strategies.

As a consequence, approaches to economic development policy changed dramatically in the late 1990s and early 2000s, as the locus of attention shifted from the national to the regional and local levels. In the Canadian context, the overwhelming preoccupation with things federal has led to a tendency to overlook the considerable degree of experimentation at both the provincial and the local level during this period or to view the growing interest in multilevel governance through the conventional lens of federal-provincial relations. However, this myopia at the national level is not shared at the local and regional levels. The diffusion of new insights into the economic development process is reflected in the gradual emergence of a new policy paradigm that is regionally and locally focused and depends on the cooperation of all levels of government, as well as other public and private sector organizations, including research-intensive universities.

This chapter explores this new policy paradigm, summarizing the various theoretical insights on which it is based. It discusses how policy design and delivery is affected in the emerging knowledge-based economy, using the experience of Canada's largest province, Ontario, and emphasizing more associative and participative forms of governance. It also discusses the emerging role of postsecondary institutions as key partners in these new types of economic development strategies. It then looks at what this approach means in practice for the evolving role of research universities; it is not just their formal role in terms of research and education that matters but also their more intangible role as key community actors and partners.

Policy Frameworks for the New Paradigm: Policy Delivery through New Forms of Governance

The emphasis on learning through networks of social relations among firms and institutions is clearly reflected in the relation between innovation systems at the national and regional levels and clusters at the local level. The innovation systems approach reinforces the observation that successful competition in knowledge-intensive industries draws on a complex set of relationships between groups of interrelated firms and supportive institutions, rather than archetypal autonomous firms (Lundvall 2005). And it provides a conceptual foundation for the answer to a key question facing policy makers, that of how best to create the conditions to stimulate innovation and competitiveness. Governance mechanisms are central to this approach. Indeed, the ability to foster durable and interactive links among a range of actors has become not only a policy goal in itself but also an important component of state power. The government's ability to cooperate and collaborate with a wide range of stakeholders has become essential to the effective exercise of economic power in innovation-based economies (Cooke and Morgan 1998).

Yet recognizing the importance of cooperation is only part of the policy challenge. As with any other economic activity, successful collaboration and cooperation are underpinned by social institutions. Trust, social norms, and loyalty—all aspects of the more general notion of social capital—lie at the core of mutually beneficial and successful cooperation. Economic development policy that seeks to strengthen the density of these associational links must include elements directed at not only interfirm links but also the underlying culture of the region or locality.

New patterns of industrial organization have emerged among growth industries in the knowledge economy, necessitating not only new policy frameworks but also new modes of governance to facilitate policy delivery. In knowledge-intensive economies, the leading growth firms are often smaller, networked, and less hierarchical, producing a variety of products developed from a supply of specialized knowledge that is based increasingly on science. Firms compete not only on price but also on their ability to learn, transforming new knowledge into products to meet new demand in yet-to-be-established markets. The central governance issues concern the mobilization of knowledge resources: accessing university research, developing an educated workforce, fostering local learning networks, and promoting collaboration. Although the term *government* is associated with the hierarchical approach to industrial policies of the past, the term *governance* implies a more flexible, multilateral process of negotiated economic development whereby political authorities at the regional and local levels partner with public institutions and private sector organizations to deliver policies.

This new type of policy structure has been captured in the literature by two related concepts: *associative governance* and *joined-up governance*. Though each term gives a slightly different emphasis to this emerging structure, their fundamental principles are similar. *Associative governance* signifies the growing shift from hierarchical forms of organization in both public and private institutions to more heterogeneous ones in which network relations are based on conditions of trust, reciprocity, reputation, openness to learning, and an inclusive and empowering disposition. According to a number of authors, this shift requires moving from reliance on public authorities associated with the state to regulate economic affairs to increased self-regulation by autonomous groups in the economy and society. This move, in turn, involves the transfer of authority and responsibility for some critical aspects of economic policy to local organizations capable of providing the required services or programs (such as vocational training or technology transfer). It also necessarily involves a more decentralized, open, and consultative form of governing. It is closely associated with the process of institutional learning and adaptation within the region (Cooke 1997).

A key challenge for the state operating in this mode is to establish the conditions under which key actors in the innovation systems—firms, associations, and public agencies—can engage in a self-organized process of interactive learning. The ability to operate in this mode depends on two major institutional departures from the way in which the Weberian concept of the bureaucratic state traditionally functions. First, it implies the devolution of power in the state system from remote bureaucratic ministries at the national level to local and regional levels of government, which are better positioned to build lasting, interactive relations with local and regional firms and business associations. Second, it may involve the delegation of certain tasks such as enterprise support services by formal government agencies to accredited business associations. Such associations can possess relevant assets, such as knowledge of and credibility with their members, that the state needs to enlist to ensure the effectiveness of its support policies. Devolving power to lower levels of government creates the opportunity for more meaningful dialogue to take place at the regional level. This point is important, because dialogue is central to the process by which parties reinterpret themselves and their relationship to other relevant actors in the local economy (Morgan and Nauwelaers 1999).

The associative model of governance affords several valuable insights into the process of governance, especially in dynamic local and regional economies. The associative model substitutes for the exclusive role of the public bureaucracy a mix of public and private roles, and it emphasizes the context of institutional structures and learning. It involves the devolution of greater degrees of autonomy and responsibility for policy outcomes to those organizations that will enjoy the fruits of the policy success or live with the consequences of its failure. According to Amin (1996), the adoption of an associative model does not imply an abandonment of a central role for the state but rather a rethinking of its role. In an associative model, the relevant level of the state has to become one of the institutions of the collective order, working with other organizations, rather than operating in its traditional command-and-control fashion. The state in this model continues to establish the basic rules governing the operation of the economy, but it places much greater emphasis on the devolution of responsibility to a wide range of associative partners through the mechanisms of voice and consultation (Amin 1996).

Equally relevant is the related concept of *joined-up governance*. The conventional bureaucratic structure, especially in a Westminster type of legislative system operating on the principle of individual ministerial responsibility, makes it necessary to develop and implement policy in bureaucratic hierarchies with clearly delineated lines of accountability. This structure has given rise to the dilemma of so-called policy silos, in which relevant components of economic development policy are often formulated and implemented within discrete bureaucracies across separate ministries or even separate divisions within the same ministry. Although this policy approach places a high premium on maintaining appropriate lines of accountability, it often fails to deliver policy in an integrated and coordinated fashion on the ground in specific localities. This traditional, hierarchical approach to policy delivery is increasingly viewed as out of touch with, and even inimical to, the more integrated geographic perspective afforded by the innovation systems approach.

A valuable alternative to the traditional hierarchical approach is a more horizontal policy process that local-level involvement can help foster, leading to what Gaffikin and Morrissey (2000) call joined-up governance. By helping break down policy silos that persist in less interconnected governance systems, such joined-up, horizontal governance allows policy to be developed and administered in a more holistic manner. In joined-up governance, key exogenous community-level issues, such as transportation, which are typically marginalized in economic development strategies despite their integral importance to successful policy outcomes, are included; they thus become endogenous to the policy process. Only through joined-up governance is it possible to ensure that the appropriate policy actors and policy instruments, regardless of their particular bureaucratic home, are brought to bear on the critical economic development challenges facing particular regions or communities.

A final theme in the literature on new forms of civic governance is the role that extrafirm institutional supports play in strengthening and sustaining interfirm dynamics within local and regional economies. There is a strong interdependence between the economic structure and the social institutions, both formal and informal, that constitute the innovation system. Many of the key factors that drive innovation and competitiveness lie outside the firms themselves. The presence or absence of these key institutional elements in a local or regional economy may affect both its innovative capacity and its potential to function as a node for cluster development.

Some universities provide engaged and dynamic community leadership in building collaborative networks and institutions at the local level (Wolfe 2005). Current research goes beyond the traditional role of universities in research and education to view them as important community actors that contribute to virtuous cycles of economic growth and development:

> [U]niversities have become significant agents of economic development. They are no longer concerned only with transferring technology to the commercial sector; they feel compelled to foster conditions for generating regional wealth (Geiger 2004, 181).

Much of this multifaceted institutional behavior that is closely engaged with the local economic community is captured in the concept of the entrepreneurial research university. The Innovation U. project in the United States provides a useful conceptual framework for characterizing these types of universities. It groups their activities into three broad functions: (a) providing mechanisms to facilitate industry-research partnerships; (b) acting as institutional enablers of entrepreneurial culture; and (c) providing boundary-spanning structures with other local institutions and firms (Tornatzky, Waugaman, and Gray 2002).

In summary, associational and joined-up governance are two dimensions of a framework for creating a form of governance that can respond effectively to the demands of the knowledge-based economy. They promote a collective process of interactive learning—not just within the state but also among firms, associations, and public agencies—that is essential to innovation in this economy. Such processes of institutional learning must extend across, and include, key actors in both the public and private sectors at all three levels of governance. In his 2003 study on successful cities and communities, Neil Bradford identifies three learning dynamics that occur when these approaches are successfully applied.

The first is a *civic learning* process that results in recognition among local organizations, in the private or the public sector, of the importance of equity, diversity, and interdependence and the need to accommodate these characteristics in their collaborations. Rather than merely accepting the need for a fair distribution of resources (equity), diversity in social relationships, or dependence on others to coordinate objectives, communities in which civic learning is successful recognize these characteristics as assets.

Equally important is the second dynamic of *administrative learning*, whereby administrators learn new skills for building relationships, seeking consensus, assessing risk, and measuring performance. Using such skills helps foster a government that is effectively engaged in its essential roles of ensuring balanced representation of social interests, addressing systemic differences in the capacity to participate, convening and organizing meetings, establishing protocols for monitoring progress, and maintaining the focus and commitment of social partners.

Finally, the culmination of successful civic and administrative learning leads to the third dynamic, that of *policy learning*. Here, feedback from the various actors within the joined-up governance process refocuses the policy agenda through street-level insights and experiences as well as new goals.

Best Practice: Learning Regions, Innovating Economies

The transition to a knowledge-based economy, with its consequent implications for policy formation in the context of associative and joined-up governance, is radically altering the design of economic development strategies. The implications of this shift began to influence the thinking of economic development agencies in the 1990s. Most significant is the fact that the emerging model has the potential to overcome some of the sources of weakness traditionally ascribed to Canadian economic development policy: lack of a strong state tradition and inability to locate responsibility for economic development policy in a strong centralized bureaucracy. In fact, the insights associated with the new model of associative and joined-up governance suggest that the very factors perceived as sources of strength for economic development strategies in the old industrial paradigm no longer are in the emerging knowledge-based economy. Similarly, new developments at the regional level in Europe and the local level in North America provide helpful examples of a new direction in regional and local economic development strategies.[1]

Innovative Approaches to Economic Development in Ontario

Historically, the economy of Ontario has been the industrial heartland of Canada, a strong manufacturing base built behind the protective shelter of tariff walls. As the country moved to a more open trading environment through successive rounds of tariff reduction in the General Agreement on Trade and Tariffs, the creation of the World Trade Organization, and the negotiation of the North American Free Trade Agreement, provincial industry was forced into successive rounds of restructuring in the 1980s and 1990s. During the latter part of this period, both the federal and the provincial governments began to dedicate increased support to the postsecondary education sector through increased research funding and creation of dedicated research networks, using the provincial Centres of Excellence program and the federal Networks of Centres of Excellence. The dynamism of the provincial innovation system was hampered to some extent by the legacy of its manufacturing culture, which had matured under tariff protection, and by a deeply entrenched individualistic business culture that made sectoral or cluster-based cooperation at the local and regional levels a distant ideal (Gertler and Wolfe 2004).

Beginning in the early 1990s, a number of notable experiments with new approaches to economic development policy began to overcome this tradition of Anglo-Saxon individualism. Although the underlying principles of associative and joined-up governance have been far from the political mainstream in Ontario during much of this period, the approach has

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[1] For a more detailed discussion of the relevance of recent European and U.S. policy approaches for the Canadian situation, see Wolfe (2002a).

been of growing interest to a wide range of economic development policy makers at the regional and local levels. The roots of the province's buildup to more associative approaches to economic development strategy can be traced to the Industrial Policy Framework introduced by the provincial government and the provincewide sector strategies that were developed as the centerpiece of that initiative (Bradford 1998; Wolfe 2002b).

The sector strategy approach was abandoned with the election of a new provincial government in 1995, but associative approaches to economic development strategy found a home in the Urban Economic Development (UED) branch of the provincial Ministry of Enterprise, Opportunity, and Innovation. The branch originated with the appointment of a special adviser on urban economic affairs in May 1998. From the outset, the approach adopted by the UED branch was to pursue a more effective strategic alignment of existing resources in the provincial government for supporting research, postsecondary education, urban development, and health as a means of promoting urban economic development. A key part of the UED branch's mandate was to build strong links between provincial and local economic development organizations in Ontario's urban regions so as to better align objectives, actions, and investments. With commitment to this approach by the UED branch, universities began to emerge as key participants in some of these initiatives, both as valuable strategic assets to be leveraged in a knowledge-based economic development strategy and as central community actors in their own right. Indeed, a key report prepared for the Ontario government at the time explicitly adopted the innovation systems approach in analyzing the potential contribution of Ontario's established network of postsecondary educational institutions to the province's economic future:

> To understand how innovation is created, it is necessary to look at the innovation systems of a jurisdiction—the interaction among the various forces and partners, including government, industry, communities, and universities, that foster innovation. All players in an innovation system unite to create an environment to support these conditions. The importance of universities is clear. Universities provide the supply of highly talented, qualified people. The ability of firms and other organizations to develop specialized expertise in applying leverage and designing innovative products and processes depends critically on the availability of suitably talented leaders and employees (Munroe-Blum 1999, 14).

The UED branch focused on the development and implementation of economic strategies and partnerships to advance industry clusters in urban regions. It worked with economic development agencies and business organizations in large urban regions to increase their capacity to support economic development in Ontario's urban regions. It did so by working with local partners to refine and implement specific economic development initiatives in their communities, in part by developing new, innovative approaches to urban and regional development. Its mandate also included broadening local partners' awareness of best practices in economic development in competing urban regions across Canada, the United States, and other countries of the Organisation for Economic Co-operation and Development (OECD).

In the late 1990s, the UED branch was involved in several initiatives across the province. In both Ottawa and Toronto, it launched major cluster studies, in partnership with local economic development agencies and community-based groups, to chart the competitiveness of the leading clusters in the local economy and their prospects for growth (ICF Consulting 2000a, 2000b). In Toronto, the study was conducted by a U.S. consulting firm in partnership with local consultants and under the direction of the Economic Development and Planning Offices of the city of Toronto. The study fed directly into the formation of the Toronto Economic Development Strategy.

The recent OECD review of territorial policy and urban initiatives in Canada painted a broadly positive picture of the process, suggesting that it "benefited from the active involvement of business, labour, academic, and community leaders" (OECD 2002, 156), although the author's own interviews with participants painted a less sanguine picture of the degree of community engagement. In part, this perception of the participants reflected the absence in Toronto of strong cohesive leadership committed to the economic success of the entire city-region, as well as the lack of key civic entrepreneurs in the economic or political sphere who were willing to assume leadership of the process of developing the cluster strategy. However, the strategy development process did lay the groundwork for subsequent initiatives that have been more successful.

The shortcomings revealed by the process associated with the original Toronto cluster study have been overcome by a new initiative called the Toronto City Summit and the subsequent formation of the Toronto City Summit Alliance. The original summit was a one-day event organized in June 2002 at the initiative of the mayor's office, with strong participation from community organizations including the United Way and the Canadian Urban Institute. It brought together a diverse group of leaders, reflecting the many communities that make up the urban area, to assess the region's strengths and challenges and to frame an agenda to respond to those challenges.

Following the successful conclusion of the summit, a coalition of more than 40 civic leaders from the private, labor, voluntary, and public sectors came together to form the Toronto City Summit Alliance. The alliance worked through the following eight months, using staff resources committed by a number of organizations to produce its own analysis of the region's economic and social situation and to formulate its own action plan. The plan, released in April 2003, sets out a broad agenda for change in physical infrastructure, tourism, research infrastructure, education and training, immigration, and social services. The release of the report was followed by a second summit in June 2003 and commitment to proceed on a number of key initiatives, including the proposal for a Toronto Region Research Alliance (Toronto City Summit Alliance 2003). What is unique about the Toronto City Summit Alliance is that the leadership has come almost entirely from the private and voluntary sectors—true civic entrepreneurs—yet the process has included many of the elements of community-based strategic planning.

Of the several initiatives launched by the Toronto City Summit Alliance, perhaps the most significant has been the creation of the Toronto Region Research Alliance (TRRA). TRRA is a coalition of leading research institutions that serves the communities in the broader Toronto region, including the greater Toronto area, the regions of Kitchener-Waterloo and Hamilton-Wentworth, and the city of Guelph. Its mission is to build the region into a leading area for research and research-intensive industry by increasing public and private research capacity, enhancing the commercialization of research, attracting new research-intensive companies to the region, and working to expand opportunities for those companies already located in the region. It focuses on expanding research capabilities in three priority areas: biotechnology and life sciences, information and communication technology, and materials and advanced manufacturing (which reflect some of the core strengths of the region's research universities).

The TRRA has been trying to convince both the federal and the provincial governments of the need to expand funding commitments to key research institutes in the region (TRRA 2005). It has achieved a considerable degree of success. Since 2005, both national and subnational governments have called for expanding the presence of federal research laboratories in Toronto and matching financial commitments by private entrepreneurs to leading research institutes in Waterloo. However, the election of a new Conservative government at the federal level in January 2006 cast some doubt on whether it will live up to the commitments made by its predecessor (*Research Money* 2006).

The city of Toronto, which was slow to capitalize on its initial cluster strategy in 1999, has recently become more engaged in using associative approaches to expand its economic development initiatives. Under the leadership of the city's economic development office and with active participation by both the federal and provincial governments, the inclusive strategy development process involved a broad cross-section of representatives of industry, government, and the educational sector. The recently released strategy document notes that Toronto's information and communications technology cluster is currently the third largest in North America in employment and one of the largest private sector employers in the region. However, it is not operating at optimal efficiency because of factors such as the lack of recognition of the sector's size and relative contribution to the local economy, the need for identification and support of its regional strengths and assets, the lack of a catalyzing influence by local champions, and the need to strengthen and reinforce the local research and education infrastructure that supports the cluster.

Among the many actions that the strategy calls for are working with the TRRA and other local organizations to improve the local research infrastructure and boost research activity. Among the actions that flow from this goal are increasing access to federal and provincial research support by local research institutions and advocating for the establishment of a major federal or provincial research or commercialization institute in Toronto focused on information and communications technology to strengthen the existing research institutions (ICT Toronto 2006). The acquisition of ATI Technologies, a leading Toronto-based video graphics company, by Silicon Valley's AMD in mid-2006 is viewed as exactly the sort of development that Toronto should be leveraging into a major research investment. The strategy is notable in the extent to which it has overcome some of the limitations of previous cluster strategy processes and the extent to which it builds on other recent initiatives, including the Toronto City Summit Alliance and the TRRA in recognizing the critical nature of the links between the region's research infrastructure and dynamic cluster development.

Ottawa is both the national capital and the second largest city in Ontario. Although it was long identified exclusively as a seat of government, it emerged in the 1980s as a full-blown high-tech cluster in its own right, having built on the strengths of the region's federal government laboratories, the two local research universities, and the community college. The competitive study of Ottawa's clusters undertaken in the late 1990s with support from the UED branch reflected the social makeup of the economic community from the outset. A key factor that differentiates the Ottawa clusters is the strength of the local institutions of collaboration and the high degree of social capital that they generate.

The linchpin is the Ottawa Centre for Research and Innovation (OCRI), a not-for-profit organization dedicated to helping the city's technology community shape its economic future. Founded in 1983 as a collaborative effort by partners from industry, the regional municipality, local institutions of higher education, and federal laboratories, OCRI has about 700 members. OCRI sponsors a wide range of corporate programs that involve up to 120 events a year and provides the members of the Ottawa area clusters with a virtually unlimited range of networking opportunities. OCRI is also involved in a dense network of partnerships with many federal and provincial organizations that are aimed at strengthening the region's innovation capabilities. These partnerships include provincially funded, university-based centers of excellence, working relationships with the Ottawa-Carleton Manufacturers Network and the Ottawa Photonics Cluster, and joint ventures with the National Research Council's Regional Innovation Centre.

OCRI was also closely involved with the Economic Generators Initiative in 1999 to 2000. That initiative was launched under the auspices of The Ottawa Partnership (TOP), a group of public and private leaders committed to advancing the local economy. TOP's mandate "is to provide leadership and advice at a strategic level, on action required to improve and grow Ottawa's economy" (ICF Consulting 2000a, i). Members include the chairs of the region's business and economic development agencies and representatives of its municipal council, the higher education sector, and the business community at large. As one of TOP's first priorities, TOP leaders decided to undertake a detailed study of the region's economic generators and to use the study to prepare a strategic plan to further develop the key engines driving the local economy. More than 300 people participated in the work of the various cluster groups that formed part of the visioning exercise and helped formulate 33 goals for promoting the growth of the seven key clusters identified as the growth generators for the regional economy.

The exercise also produced a higher-order set of flagship initiatives designed to work across the individual clusters to benefit the regional economy as a whole. The level of participation in the Economic Generators Initiative engendered great expectations in the region about the results that would follow from the presentation of the report in June 2000 (ICF Consulting 2000a). Unfortunately, the report was released just as the high-tech sector entered a serious downturn. Despite the impact of the recession, TOP, in cooperation with local economic development agencies and the municipal council, forged ahead with planning for many of the cluster and flagship initiatives outlined in the report. Of the 33 cluster initiatives, 10 have achieved tangible results. New steps have been taken to strengthen the region's photonics and biotechnology clusters with the formation of the Ottawa Biotechnology Incubation Centre and the Ottawa Photonics Research Alliance.

A review and update of the report was released in January 2003 (ICF Consulting 2003). A key goal set out in the updated report was to reenergize the cluster approach developed in the Economic Generators Initiative. The objective was to engage the individual clusters identified in the initial report in working with a range of community partners, to strengthen each element of the city's innovation system, and to collaborate on the flagship initiatives designed to strengthen all the clusters. The recent report, "Innovation Ottawa," set out a strategy for strengthening the links between the region's research infrastructure—especially its postsecondary education sector and national laboratories—and the local sources of enterprise within existing and emerging clusters (ICF Consulting 2003). The report elaborated a vision of what the region should aspire to become: a leading example in North America of a truly networked and collaborative region that mobilizes its information infrastructure to link every firm and institution; a home to a disproportionately large share of the creative class; an integrated region that successfully brings together the elements of research, development, and commercialization; and a dynamic region that generates a diverse and continually evolving set of clusters (ICF Consulting 2003).

A more recent initiative launched by the Ontario government, the Biotechnology Clusters Innovation Program (BCIP), warrants consideration in this context. The provincial minister of enterprise, opportunity, and innovation launched Ontario's biotechnology strategy on June 7, 2002. As part of that strategy, the government announced a new program initiative: the BCIP. The overall goal of Ontario's biotechnology strategy was to make the province one of the top three biotechnology jurisdictions in North America. The BCIP was a component of that strategy, with the goal of accelerating the development of Ontario's biotechnology clusters by supporting the commercialization of infrastructure projects and the diffusion of biotechnology-related innovations into knowledge-based or traditional industry sectors.

The program consisted of two distinct phases. In the first phase, the government supported the development of plans that address the innovation capacity of Ontario's regional biotechnology clusters. It provided funding up to Cdn$200,000, on a matching basis, to regional consortia for the development of a biotechnology cluster innovation plan. The second phase was designed to support the development of infrastructure such as commercialization centers, research parks, and other regional initiatives that promote entrepreneurship and innovation. Eleven regional consortia developed regional innovation profiles and corresponding regional cluster strategies in the first phase of the program. Between late 2003 and early 2005, provincial officials held a series of seminars with representatives of the 11 consortia, as well as separate meetings with the individual groups.

In the provincial budget of May 2005, the province launched the follow-on phase of the program in the form of a series of regional innovation networks. These networks are described in a budget document as "multi-stakeholder, regional development organizations established with Provincial funding that support partnerships among business, institutions, and local governments to promote innovation" (Ontario Ministry of Finance 2005, 110). These networks are mandated to expand beyond their original focus on the life sciences to include other areas of innovation excellence, such as information technology, energy conservation, and advanced materials, depending on local strengths and opportunities.

The networks are also described as constituting part of a multilayer commercialization network that includes the province, multiregional groups focused on key technology areas or industrial sectors, and the original regional consortia described above. The constituent parts of the network support two complementary sets of activities—those that build on and connect the components of the network and those that contribute to a more effective alignment of existing federal, provincial, and local research infrastructure and related innovation assets. A key function is to increase the knowledge flow and build links between existing postsecondary and other public research institutions and firms, so as to build industrial capacity for the uptake and adoption of new research and technology. The overriding goal of the regional innovation networks is to increase regional innovation capacity by addressing commercialization gaps in the existing level of support for small and medium enterprises in innovation-intensive sectors and clusters. The program also aims to develop strong networks that can improve the accessibility of the public research infrastructure and resources for firms. Although the transition from the BCIP to these networks is still in its early stages, overall the program displays many of the positive features of bottom-up strategic planning that have been described in the preceding sections. Ultimately, the goal of the program's developers is to link the entire infrastructure of research institutions and innovation support organizations into denser clusters at the regional and local levels.

Lessons for Policy: Principles, Institutions, Practices

The preceding examples present a picture of an emerging paradigm for economic development policy based on the underlying principles of associative and joined-up governance. The current challenge for economic development policy is to ensure that public sector agencies learn to work in a new and more effective way with a range of public and private sector partners. The same recommendation applies to the current mix of policies and programs—provincial and federal—available to support innovation and economic development. The new wave of innovation policies and programs that gained support in the 1980s and 1990s created a dense network of research institutions and technological infrastructure. Those initiatives at both levels of government have strengthened the research capacity of the province. The increased emphasis on research-industry links has also improved knowledge flows within the regional innovation system. On the downside, the initiatives have also resulted in a plethora of programs, making it virtually impossible for bureaucrats, let alone private firms, to track them all.

Achieving better integration and coordination of available programs and policy instruments can best be accomplished at the level of the local and regional economies from the perspective of strategic clusters or local and regional innovation systems. It requires a greater degree of coordination among all three levels of government and their economic development agencies. No one level has a monopoly on the policy instruments and approaches necessary for an effective economic development strategy. Many policies and programs have been implemented in a traditional, top-down, bureaucratic fashion, administered by individual departments or agencies with little cross-jurisdictional coordination and often little attention to the broader implications of the program for cluster development in the local or regional innovation system. The coordinated approach to economic development policy requires a more integrated approach to policy planning at the governance level, rather than a new round of institutional renovation at the federal, provincial, or local level.

As the discussion in the preceding sections make clear, this approach has been applied in a number of different contexts in Ontario. The sector strategy development process in the early 1990s, the cluster development process in leading urban centers in the province, the BCIP, and—most recently—the transformation into regional innovation networks all evince elements of the approach to economic development policy envisioned in this chapter. The key challenge is to extend the approach to a broader cross-section of provincial economic development policy and to use the resulting planning exercises as a criterion for allocating program dollars. The strategic planning approach to economic development policy does not require significant new public spending but rather is intended to produce a new set of criteria to be used in determining the allocation of existing program dollars in the economic development policy envelope. At most, the provincial and federal governments might choose to use relatively small amounts of new program funding to stimulate the kind of planning exercises described above, as in the case of the BCIP. However, they should also recognize that many programs at both the federal and provincial levels currently contain budgetary allocations that can be applied for this purpose (OECD 2002).

Effective economic development policy builds on successful experiments with associative governance. There is growing recognition that such development policies work most effectively when the direct beneficiaries play a direct role in both their design and their implementation. This approach involves developing a rolling set of innovation strategies at the cluster, local, and regional levels to ensure that the existing R&D infrastructure, including research-intensive universities and economic development programs, is used to maximum advantage—to assess existing needs and identify gaps in the program array. Ensuring that the mix of research infrastructure and innovation programs is used to maximum advantage for the local economy requires an ongoing process of reflexive monitoring and social learning. The success of the recent initiatives at the local level in Ontario provides an important illustration of how other jurisdictions can adopt and use these processes.

References

Amin, Ash. 1996. "Beyond Associative Democracy." *New Political Economy* 1 (3): 309–33.

Bradford, Neil. 1998. "Prospects for Associative Governance: Lessons from Ontario, Canada." *Politics and Society* 26 (4): 539–73.

———. 2003. *Cities and Regions That Work: Profiles of Innovation*. Ottawa: Canadian Policy Research Networks.

Cooke, Philip. 1997. "Institutional Reflexivity and the Rise of the Region State." In *Space and Social Theory: Interpreting Modernity and Post-Modernity*, ed. Georges Benko and Ulf Strohmayer, 285–304. Oxford, U.K.: Blackwell.

Cooke, Philip, and Kevin Morgan. 1998. *The Associational Economy: Firms, Regions, and Innovation*. Oxford, U.K., and New York: Oxford University Press.

Gaffikin, Frank, and Mike Morrissey. 2000. "Participation in Planning in These New Times." In *Urban Renaissance: Belfast's Lessons for Policy and Partnership*, 181–201. Paris: Organisation for Economic Co-operation and Development.

Geiger, Roger L. 2004. *Knowledge and Money: Research Universities and the Paradox of the Marketplace*. Stanford, CA: Stanford University Press.

Gertler, Meric S., and David A. Wolfe. 2004. "Ontario's Regional Innovation System: The Evolution of Knowledge-Based Institutional Assets." In *Regional Innovation Systems*, 2nd ed., ed. Philip Cooke, Hans-Joachim Braczyk, and Martin Heidenreich, 91–124. London: Taylor and Francis.

ICF Consulting. 2000a. *Choosing a Future: A New Economic Vision for Ottawa*. Report for the Ottawa Economic Generators Initiative. Toronto: ICF Consulting.

———. 2000b. "Toronto Competes: An Assessment of Toronto's Global Competitiveness." City of Toronto Economic Competitiveness Study. Economic Development Office, Toronto, ON.

———. 2003. "Innovation Ottawa: A Strategy for Sustaining Economic Generators." ICF Consulting, San Francisco, CA.

ICT Toronto. 2006. "An Information and Communication Technology (ICT) Cluster Development Strategy for the Toronto Region." Toronto Economic Development, Toronto. http://www.toronto.ca/business/pdf/ict_toronto_final_report.pdf.

Lundvall, Bengt-Åke. 2005. "National Innovation Systems—Analytical Concept and Development Tool." Paper presented at the Danish Research Unit for Industrial Dynamics (DRUID) Annual Conference, Copenhagen, June 29.

Morgan, Kevin, and Claire Nauwelaers. 1999. "A Regional Perspective on Innovation: From Theory to Strategy." In *Regional Innovation Strategies: The Challenge for Less Favoured Regions*, ed. Kevin Morgan and Claire Nauwelaers, 1–18. London: Her Majesty's Stationery Office.

Munroe-Blum, Heather. 1999. "Growing Ontario's Innovation System: The Strategic Role of University Research." Report prepared for the Ontario Ministry of Training, Colleges, and Universities, the Ontario Ministry of Energy, Science, and Technology, and the Ontario Jobs and Investment Board, Toronto.

OECD (Organisation for Economic Co-operation and Development). 2002. *OECD Territorial Reviews: Canada*. Paris: OECD.

Ontario Ministry of Finance. 2005. "Paper B: Achieving Our Potential: Progress towards a New Generation of Economic Growth." In *2005 Ontario Budget: Budget Papers*, 91–125. Toronto: Ontario Ministry of Finance.

Research Money. 2006. "Ontario Government Commits $100 Million to Waterloo Institutes." 14 April.

Tornatzky, Louis G., Paul G. Waugaman, and Denis O. Gray. 2002. *Innovation U.: New University Roles in a Knowledge Economy*. Research Triangle Park, NC: Southern Policies Growth Board.

Toronto City Summit Alliance. 2003. "Enough Talk: An Action Plan for the Toronto Region." Toronto City Summit Alliance, Toronto.

TRRA (Toronto Region Research Alliance). 2005. "Engaging Innovation." TRRA, Toronto. http://www.trra.ca/PDF/engaging.pdf.

Wolfe, David A. 2002a. "From the National to the Local: Recent Lessons for Economic Development Policy." In *Urban Affairs: Back on the Policy Agenda*, ed. Caroline Andrew, Katherine A. Graham, and Susan D. Phillips, 239–64. Montreal: McGill-Queen's University Press.

———. 2002b. "Negotiating Order: Sectoral Policies and Social Learning in Ontario." In *Innovation and Social Learning: Institutional Adaptation in an Era of Technological Change*, ed. Meric S. Gertler and David A. Wolfe, 227–50. Basingstoke, U.K.: Palgrave.

———. 2005. "The Role of Universities in Regional Development and Cluster Formation." In *Creating Knowledge, Strengthening Nations: The Changing Role of Higher Education*, ed. Glen A. Jones, Patricia L. McCarney, and Michael L. Skolnik, 167–94. Toronto: University of Toronto Press.

CHAPTER 8

University-Industry Links in the Japanese Context

Between Policies and Practice

Juan Jiang, Yuko Harayama, and Shiro Abe

The need to strengthen the knowledge-based economy and its underlying research and development (R&D) activities has prompted the Japanese government to introduce a number of technology policies. These policies especially focus on a more active role by universities. In support of the policies, the Basic Law for Science and Technology of 1995 was introduced. The 1995 law gives the government legal power to promote the advancement of science and technology (S&T). This legislation set the stage for the introduction of five-year S&T basic plans.[1] The underlying motivation for introducing the five-year plans was to vitalize the Japanese economy through the creation of spinoff and start-up companies, as well as through the opening of new industries that were induced by technology transfers from universities and research institutes.

[1] The first basic plan covered the period from 1996 to 2000, and the second one covered 2001 to 2005. The cabinet adopted the third plan on March 28, 2006.

However, the need for university-industry links (UILs) has been voiced at other times in Japan's history also. Throughout the past century, Japanese universities have interacted with industries. However, the rationale for such interaction and the way in which it took place have differed in specific periods. For example, UILs have encompassed the training of engineers; the development of generic technologies; and, most recently, the building of innovation capability that is based on the accumulation of knowledge.

This chapter attempts to identify the evolutionary path of UIL-related policies in Japan through a historical analysis of Japanese technology policy and a case study based on Tohoku University. We start, in the following section, with a brief history of the Japanese technology policy in the post–World War II period (late 1940s to mid-1990s), with an emphasis on the expected role of universities at that time. Then we look at the past experiences of UILs in the Japanese context, through a historical analysis of Tohoku University, which was established in 1907 and which pioneered the movement toward the entrepreneurial university. This movement in Japan coincided with the period during which, in the United States, the Massachusetts Institute of Technology (MIT) created the model of the entrepreneurial university—an institution that combined teaching and research with the capitalization of knowledge. In the following section, we describe the policies introduced to stimulate UILs since the end of the1990s. These recent UILs can be termed *government-led UILs*. We conclude by reassessing the role of the government in encouraging UILs.

A Brief History of the Japanese Technology Policy

Modern Japanese technology policy was launched shortly after World War II; the early focus was on the assimilation of foreign technologies.

The First White Paper on Technology

The end of World War II marked the shift away from defense-oriented technology policies and toward economic ones stressing social issues. The first white paper on technology, *The State of Our Country's Industrial Technology* (ITA 1949), set the tone and oriented later policies. It expressed the concern of Japanese officials over the state of technological capabilities and contained pragmatic proposals for improving them.

The white paper identified a number of the weaknesses of Japanese industry, including:

- A lack of domestically developed technology. This weakness was partly attributable to the myopic attitude of Japanese industrialists, who would foresee short-term returns and who preferred to import technology rather than to invest in costly R&D activities.
- Difficulty in translating the research results accumulated within academia into industrial products. This weakness was attributable to the lack of applied R&D.

The white paper proposed to enhance applied R&D and to solicit the active engagement of universities in technology transfer. The idea of an innovation system that was based on the patent system, standardization, quality control, contributions of academic societies, and high-level training of engineers was already present, and the white paper urged strong political support to develop a technology-based economy.

Large-Scale Industrial R&D System

During the 1950s, the import of technologies gathered momentum. Japan was successful in assimilating, adapting, and improving imported technologies. During the 1960s, the production process greatly improved, backed by a strong focus on quality control. A new trend in Japanese innovation system appeared during that period: private companies started to set up research laboratories. Known as *central research laboratories*, these labs were devoted to developing their own technologies. However, despite their efforts to develop indigenous technology, few technological breakthroughs actually emerged. The efforts of industry concentrated mainly on improving existing or imported technologies.

After this start, in 1966 the Ministry of International Trade and Industry (MITI) implemented the Large-Scale Industrial Research and Development System. Commonly called "Big Projects" (Group for Promoting the Commemoration of the 20th Anniversary of Big Projects 1987), the system had the aim of supporting high-cost, long-term, and high-risk research projects, with a potential to produce technological breakthroughs and large spillovers, but with little chance of being initiated by private companies in the absence of government intervention. By selecting a few technological areas and making available substantial subsidies on one hand, and by combining the resources of private companies, universities, and national research laboratories on the other, the government sought to consolidate Japan's technological base in promising industries and subsequently to increase the economy's competitiveness. It is worth noting that the concept of Big Projects was based on explicit commissioning of research. Each firm or research entity would individually execute one part of a research project, so no on-site research collaboration was planned. Also, key actors were private companies, not universities, though universities were expected to provide expertise on some fundamental issues. Thus, under the umbrella of Big Projects, universities, national research laboratories, and private companies were partners and collaborators, but only limited interaction took place in reality.

Besides MITI, two other government agencies also promoted UILs. The Science and Technology Agency (STA) introduced the System for Promotion of Coordinated and Creative Science and Technology in 1981 (Nihon Keizai Chosa Kyogikai 1988), and the Ministry of Education (Monbusho) implemented cooperative research with the private sector in 1983 and began establishing centers for cooperative research in 1987.[2] The STA's system consisted of contract-based five-year joint research projects involving industry, the universities, and the state. The projects sought to create technological seeds. The Ministry of Education, which is the regulatory authority on higher education, focused on stimulating research cooperation between national universities and industry. The program to develop cooperative research with the private sector gave private sector researchers and engineers open access to university laboratories, and the centers for cooperative research provided the space within national university campuses to carry out cooperative and commissioned research, as well as provided training for private sector engineers. All these policies underscored the need for university-industry research cooperation.

Toward a Nation Based on the Creation of Science and Technology

The 1990s, a period in which Japan faced prolonged economic stagnation, are often called "the lost decade." This period of stagnation, however, prompted the enactment of the Basic Law for Science and Technology of 1995. This legislation enabled the government to pursue and elaborate the concept of a nation based on the creation of S&T. The law required the costly and long-term engagement of the public sector. It emphasized cooperation among national research laboratories, universities, and the private sector, as well as the right balance among basic research, applied R&D, and training of researchers.

The idea for such a law was conceived in 1968, when the Council for Science and Technology recommended that the government formu-

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[2] In 2000, 53 centers had been founded within national universities.

late a basic law for S&T (Group for Promoting the Commemoration of the 20th Anniversary of Big Projects 1987). However, the effort failed, because academia strongly opposed the idea of more formal university-industry cooperation (Haseda 1996).

In the 1990s, social pressure on academia to become more efficient and accountable increased. In that context, closer ties with industry were used to justify public support for university-based research activities. Also, Japan's shift from being a follower to a pioneer in the innovation race required stronger complementarity between basic and applied research, which in turn argued for greater cooperation between universities and industry and collaboration among S&T-related ministries. The 1995 law, accompanied by these forces, led to the foundation of an integrated innovation system based on the industry-university-state tripartite cooperation.

Some Facts from the History of Tohoku University

Given this unfolding of policies, how have Japanese universities managed their relations with industry in the past? To better understand the process, we focus on the case of Tohoku University.

A Movement toward an Entrepreneurial-Type University

Tohoku University was founded by the Imperial Order of 1907 as the third imperial university in Japan after the University of Tokyo and Kyoto University. It is located in Sendai, a key regional city serving as the node for the Tohoku (northeast Japan) region.[3] Tohoku University catered to the rising demand for skilled workers in the aftermath of World War I and acquired a number of specialized colleges, such as the College of Agriculture and School of Engineering.

During this period of expansion, the academic seeds that had been planted by the founding fathers of Tohoku University blossomed in terms of inventions, such as KS magnetic steel (1917) by Kotaro Honda and the Yagi antenna (1926) by Hidetsugu Yagi, and in terms of the establishment of two engineering research institutes: the Institute for Materials Research (IMR) and the Research Institute of Electrical Communication (RIEC). Financed with contributions from private companies, the precursor of IMR started out in 1915 as a pioneer institution affiliated

[3] Other imperial universities were also established in key regional nodal cities, such as Osaka and Nagoya.

with the Tohoku University and became a part of the university in 1922. IMR attracted research funds from the industrial sector, and its research proved to be unusually fruitful. RIEC was established in 1935.

Because Sendai was not an industrial center, these two schools could pursue research alongside teaching. The research contributed substantially to the development of Japan's materials and electronic industries. This approach was an embodiment of the ideas of professors Honda and Yagi. Honda asserted that no real industrial development could be attained without basic research in major scientific fields (Tohoku University 1966). Yagi claimed that only the pursuit of new and creative research would allow Japan to achieve technological parity with the West (Yagi 1953).

In both institutes, although the emphasis was on basic research, many of the findings were patented, and several achieved commercial success. Also, the local spillovers were significant and resulted in the formation of businesses such as Toyo Blades (1921), Japan Heat Wire Limited Partnership (1926), Tohoku Metal Industry (1933), and Tohoku Steel (1937).

Support for High Economic Growth

In the post–World War II period, after the reconstruction of basic infrastructure, Japan resumed the path of economic growth in the mid-1950s. In the Sendai area, two major initiatives were launched in the early 1960s. In accordance with the central government's plan to increase the number of students in the fields of the science and engineering, the science and engineering faculties of Tohoku University were expanded. Also, Tohoku Industrial Technology Development Society, the first incubator in Japan that was based on the American model, was established within the campus of Tohoku University (Development Bank of Japan 1989).

In the case of MIT, the university-industry dynamic continued in the post–World War II period, fostering entrepreneurial enterprises and advancing the university's research capabilities and technical expertise (Rosegrant and Lampe 1992). By contrast, Tohoku University needed to determine how to extend and reconstruct the creative tradition of the prewar period. One step in this direction was the establishment of the Semiconductor Research Promotion Association (1961), which derived its impetus from a patented coinvention by professors Yasushi Watanabe and Jun-ichi Nishizawa and which was supported by the major Japanese electronics companies. The research institute was committed to Honda's philosophy of "verification through experiments and reverification through university-industry cooperation" (Nishizawa 1992).

A Strategy for Regional Development

By the 1980s, some professors at Tohoku University who had been conducting comparative regional studies devised a strategy for the construction of a future industrial society—a bottom-up and innovation-oriented regional development project for the Tohoku region (Abe 1997). The strategy won regional support and was instrumental in bringing together 7 prefectural governments, 7 federations of chambers of commerce and industry, and 10 national universities in the Tohoku region. It also convinced the business world, members of parliament, and the central government. According to the professors' strategy, the mission of the university was to pursue enhancement of the region's capabilities in the area of science and technology but also to augment intellectual skills in other areas, and to forge new regional-based industrial dynamics. It was, in effect, a renaissance movement to revive a tradition of exploring new disciplines, which would connect scientific training and research to practical application in a globalized knowledge economy. Implementation of the strategy has entailed developing a systematic institutional structure, as well as designing a research-friendly environment. From these academic initiatives, 14 R&D corporations have been established through joint investments by the national government and private companies.

The case of Tohoku University illustrates that the notion of an entrepreneurial-type university was present in the Japanese university system from the early stages and that, in certain cases, some universities moved a step ahead of the government initiatives.

Government-Led UILs

In the confused aftermath of the bursting of the economic bubble at the beginning of 1990s, the Basic Law for Science and Technology of 1995 laid down the framework for Japan's S&T policy for the 21st century (Omi 1996), as noted earlier. It marked the first step toward the technology-transfer model of UILs.

Advent of the Technology-Transfer Model

The first S&T basic plan, which was adopted by the government in 1996, proposed (a) raising investment in R&D to the level of Western countries, (b) creating a competitive R&D environment, (c) improving R&D capability in the private sector, and especially (d) reinforcing university-industry cooperation. Indeed, universities were expected, as knowledge-creating institutions, to become major players and to leave behind their ivory tower image. The measures taken by the government along this line included the development of various legal frameworks to promote UILs and a number of policy programs propelled by those links, such as the Japanese versions of the technology licensing office (TLO), the U.S. Bayh-Dole Act, and the U.S. Small Business Innovation Research Program (Jiang and Harayama 2005a).

Promotion of technology transfer from universities was government based. The government observed that inventions made within universities were underexploited and recognized that valorization of these dormant technologies in terms of new products or creation of frontier industries would be of social value. In general, technology transfer takes place on the basis of a case-by-case contract or an informal agreement between a faculty member and a private company, which results in a limited return to the inventor and his or her affiliated institution. Thus, the Law for Promoting University-Industry Technology Transfer, often called the Law on TLOs, was implemented in 1998 to create a "virtuous cycle of technology transfer" by facilitating the patenting and licensing of privately patentable inventions to generate a financial return that could be reinvested in research activities within the university.

The second S&T basic plan, covering 2001 to 2005, built on the first plan and on a number of reports on the promotion of UILs that were presented by various ministerial commissions (Omi 2003). In making the case for UILs, these ministerial reports emphasized the need for transferring university technologies to industrial use, for patenting intellectual property of universities, and for commercializing university research results. They paved the way for policies to strengthen industrial technology and create new industries and helped promote such measures as Fostering University-Launched Ventures Businesses (2001), the Industrial Cluster Project (2001), and the Knowledge Cluster Initiative Project (2002) (Jiang and Harayama 2005b).

Reactions of Tohoku University

On the basis of those policy lines, new frameworks for UILs have been constructed and programs for promoting R&D and creating new enterprises have been put forward. At Tohoku University, for example, the New Industry Creation Hatchery was established in April 1998 to spur domestic industries by leveraging the intellectual resources accumulated at the university. The Fluctuation Free Facility for New Information Industry (an industry-oriented research facility) and the Hatchery Square (an incubator) were dedicated in 2000 and 2002, respectively, and Tohoku Technoarch Co., Ltd. (a TLO) was established in 1998. In 2004, when Tohoku University became an independent legal entity, the university established the Office of Research Promotion and Intellectual Property.

Within the framework of government-led UILs, the number of collaborative R&D projects between Tohoku University and companies throughout Japan has grown since the late 1990s, and it almost doubled between 1998 and 2002. But the vast majority of collaboration partners are large enterprises, and the number of collaborative projects with companies in the Sendai area remains limited, amounting to around 10 percent of the total. Similarly, a number of spinoff firms emerged during this period, and Tohoku University ranks among the top five universities in Japan with regard to the number of spinoff companies (METI 2005). However, those companies do not always stay in the Sendai area (Tohoku University 2002).

Conclusion

The evolution of Japanese technology policy shows that it is not limited to technological advancement; rather, economic and institutional implications are significant. Although a clear philosophy was expressed as early as 1949 in a white paper, the Japanese technology policy has often been dictated by the catch-up imperative. The economic stagnation of the 1990s, however, propelled a shift in technology policy.

Our historical study of the Tohoku University has several implications. Tohoku University originated a movement toward an entrepreneurial-type university that can be an effective and creative inventor and transfer agent of both knowledge and technologies through the alignment of industrial development and that has both research and teaching as its principal academic missions. These UILs have been initiated by entrepreneurial faculty members, within a framework of government technology policies encouraging links.

The government policies and the initiatives of universities themselves have opened the door of university links with small and medium enterprises by clarifying the rules of game and by ensuring strong government support for UILs, including those between start-up companies and small local universities. It is evident that Japanese universities, including Tohoku University, are responding positively to the government incentives to strengthen UILs; all UIL-related indicators, such as the number of collaborative research projects, spinoffs, and licensing contracts, have increased since the end of the 1990s. We also observe that economic contribution, in particular through UILs, is now recognized as the third mission of Japanese universities, after education and research; that recognition represents a major shift in attitudes.

The Japanese government has played a dominant role in strengthening UILs. Once a UIL-friendly environment has been created, what should be the next step? Should the government maintain the pressure on UILs, or switch its role from initiator to catalyst? What is certain is that the way the Japanese government steers UILs will have a deep effect on the capacity of the nation to innovate.

References

Abe, Shiro. 1997. "Regional Policies and the Re-interpretation of Local-Regional Culture and History." In *The Recovery of Histories in Tohoku*, ed. Nobuo Watanabe, 272–304, Tokyo: Kawade Shobo Shinsha.

Development Bank of Japan. 1989. "The Trend of Science Park Building and Regional Vitalization." Chosa 136, Development Bank of Japan, Tokyo.

Group for Promoting the Commemoration of the 20th Anniversary of Big Projects [Ogata kogyogijutsu kenkyu kaihatsu seido 20 shunen kinen jigyo suishin dantai rengokai]. 1987. *Ogata project 20 nen no ayumi: Wagakuni sangyo gijutsu no ishizue wo kizuku*. [*Twenty Years of Big Projects: Founding the Cornerstone of Our Country's Industrial Technology*.] Tokyo: MITI Chosakai.

Haseda, Koji. 1996. *Science and Technology Basic Law: The Hogaku Seminar 499*. Tokyo: Nihon Hyoronsha.

ITA (Industrial Technology Agency). 1949. *Wagakuni kokogyo gijutsu no genjo*. [*The State of Our Country's Industrial Technology.*] Tokyo: Kogyo Shinbun Sha.

Jiang, Juan, and Yuko Harayama. 2005a. "Cluster Programs and University-Industry Partnership." *Journal of Science Policy and Research Management* 20 (1): 4–11.

———. 2005b. "The Development of Regional Science and Technology Policy in Japan, in Contrast with the U.S. and EU." *Journal of Science Policy and Research Management* 20 (1): 63–77.

METI (Ministry of Economy, Trade, and Industry). 2005. "Results of Basic Research on University Spinoff Companies, FY2004." METI, Tokyo. http://www.meti.go.jp/press/20050425002/20050425002.html.

Nihon Keizai Chosa Kyogikai. 1988. *Shin ni kokusaiteki na sozoteki kenkyu no ba ni—sangakukan kyoryoku no arikata-chosa hokoku*. [*Truly International Creative Research Place—Model of Industry-University-State Cooperation.*] Tokyo: Nihon Keizai Chosa Kyogikai.

Nishizawa, Jun-ichi. 1992. *NHK Ningen Daigaku*. [*A Genealogy of Originality*.] Tokyo: NHK Shuppan.

Omi, Koji. 1996. "Science and Technology-Based Nation." Yomiuri Shimbun, Tokyo.

———. 2003. "Kagakugijutu de nihon wo tsukuru." ["Build Japan on Science and Technology."] Toyo Keizai Shinpo Sha, Tokyo.

Rosegrant, Susan, and David Lampe. 1992. *Route 128: Lessons from Boston's High-Tech Community*. New York: Basic Books.

Tohoku University. 1966. *The 50 Years' History of the Institute for Materials Research*. Sendai: Tohoku University.

———. 2002. "Research on Situation in University Spinoff Companies." Research Corporation Section, Tohoku University, Sendai.

Yagi, Hidetsugu. 1953. *Gijutujin yawa*. [*Night Tales of Engineers*.] Tokyo: Kawade Shobo.

CHAPTER 9

University-Industry Links

Regional Policies and Initiatives in the United Kingdom

Mike Wright

Universities may have significant direct and indirect effects on their local economies. Although universities have long-established effects on local income as employers and consumers of services, their indirect effects through links with industry are attracting growing research and policy interest. A general premise of this attention is the perceived scope to enhance these links to further facilitate the transfer of knowledge and technology.

The nature of university-industry links and policy concerning them may vary in different institutional contexts (Wright, Clarysse, and others 2006). A number of initiatives have been developed to stimulate such links. The purpose of this chapter is to outline and discuss regional and local initiatives that have been taken to develop universities' interaction with industry in the United Kingdom.

First, the role of regional development agencies (RDAs) is outlined. The chapter then considers initiatives relating to a range of knowledge- and technology-transfer activities comprising support for collaborative research, innovation, and consulting; for the development of incubation centers and enterprise hubs; for specific long-term research partnerships; for the recruitment and development of fellows to facilitate technology and knowledge transfer; for spinning-out ventures and licensing; for graduate and researcher mobility; and for education and networking schemes. The available evidence on the effects of the schemes is then reviewed. Finally, some concluding comments are made.

Regional Development Agencies

At the local and regional level in the United Kingdom, local government and chambers of commerce have relatively little involvement in the development of significant university-industry links relating to knowledge and technology transfer. Rather, increasing emphasis was placed on the role of RDAs in the U.K. Treasury's *Science and Innovation Investment Framework 2004–2014* (Her Majesty's Treasury 2004). This policy document follows the *Lambert Review of Business-University Collaboration*, which made a number of recommendations to improve such links (Lambert 2003).

Since April 2005, RDAs have been tasked with providing a broader spectrum of assistance to develop more productive links between universities and industry. The role of RDAs complements national third-stream funding, which builds university capacity for knowledge transfer.

University-industry collaboration has now been incorporated as a measure of RDA performance; targets are being set. The importance of knowledge transfer and promotion of university-industry collaboration is to be reflected in regional economic strategies. RDAs are encouraged to develop strategies to ensure that science and technology in a region's universities and companies are of the highest caliber.

As an example, the Northwest Regional Development Agency is funding science projects, giving direction to major cluster-strengthening projects, developing measures against which to assess progress and identify actions, and establishing a science fund to support new science infrastructure projects.

Initiatives to Support Collaborative Innovation

A number of initiatives have been introduced to support collaborative innovation between universities and industry. One such initiative is the creation of industrial collaboration centers. Yorkshire Forward created 14 centers of industrial collaboration (CICs) between 2002 and 2005 at a cost of £11 million. The CICs are focused on different high-tech sectors. By the end of 2005, 1,000 projects had been completed. Yorkshire Forward claims that these projects had generated £26 million of gross income and created or safeguarded 250 jobs.

Under the scheme, CICs are accredited on the basis of world-class facilities and a track record of successful collaboration. Funding is provided to appoint a commercial manager who has hands-on industrial experience. The CIC director typically has an international research record. The CICs have a scientific advisory board of leading academics and industrialists. The intention is that the CICs will provide a business-friendly environment to facilitate university-industry collaborations.

A specific CIC case is the Materials Analysis and Research Services CIC, which is part of the Materials and Engineering Research Institute at Sheffield Hallam University. This CIC provides standard test facilities, infrared consultancy services, and up to full-scale contract research programs. The CIC has enabled the Medical House to work with Sheffield Hallam University to develop an insulin delivery system for treatment of diabetes.

A second example is the collaboration initiative facilitated by the East Midlands Development Agency between Nottingham Trent University and the University of Nottingham. This initiative, called BioCity, involves the creation of world-class laboratories, equipment, and offices. These facilities allow scientists and entrepreneurs to work at the forefront of commercialization of research in health and biotechnology.

A further mechanism for developing collaborative initiatives is the deployment of regional technology advisers to build networks within and between regions.

Incubation Centers and Enterprise Hubs

Strategies have been introduced to develop clusters of innovation that bring business services, venture capital, and technological support to entrepreneurs. The emphasis is on exploiting local R&D strengths.

For example, the Southeast England Development Agency has established 17 enterprise hubs. Each hub is supported by at least one university or research center. The hubs provide incubation space and support businesses in specific high-tech clusters. Similarly, the East Midlands Incubation Network is a regionwide network with a focus on facility management and support for incubatee companies.

Long-Term Research Partnerships

Given the nature of much high-tech research, a need to develop long-term partnerships between specific universities and firms has been recognized. The U.K. government has provided a sum of £30 million to establish five university innovation centers across the United Kingdom. The intention is for the partnership model of industry and university links to be used to develop sectors of strategic importance to the regions.

For example, the East Midlands Development Agency, BAE Systems, and Loughborough University have come together to form such a center at a cost of £4.5 million. The focus of the Systems Engineering Innovation Centre is on providing a framework for the integration of people, processes, tools, and technology to improve management of risk, product configurations, and technology insertion for development of innovative products. The aim is to attract research scientists and engineers from universities and industry to work together. The Systems Engineering Innovation Centre has buildings, including labs and conference facilities, specifically built for this purpose.

Innovation and Regional Fellowships to Facilitate Academic-Led Commercialization

In the traditional noncommercial university environment, mechanisms are needed to raise awareness and to facilitate the commercialization of technology developed in universities. The Higher Education Reach-Out to Business and the Community (HEROBC) Scheme provides a mechanism to facilitate commercialization of technology developed within universities.

An example is the case of three East Midlands universities (the University of Nottingham, Loughborough University, and the University of Leicester), which obtained under the HEROBC Scheme £550,000 for the period from 2000 to 2004. This sum was later increased by £200,000 when two other universities were added to the scheme. With the funding, the universities established the Innovation Fellowship Fund. Over the period of the funding, 52 fellows were employed to encourage and facilitate academic-led commercialization.

The initiative has also involved the establishment of the Regional Fellowship Fund. Seven fellows and a regional coordinator, whose task is to encourage strategic engagement in regional development, were appointed. Importantly, the initiative has been able to secure follow-on funding for 2004/05, providing continuity and longevity for the scheme.

Boundary-Spanning Schemes

An important concern is that university-industry links may not develop because academics and businesspeople may effectively speak different languages. There is thus a need for individuals who can act as intermediaries or boundary spanners between the two areas. This concern suggests a requirement for the development of local policies to enable the development and recruitment of individuals who can perform boundary-spanning roles. These individuals will need to be able to transfer knowledge by building links between academics and business. The links might usefully involve the development of understanding of business and market concepts and the identification of customers, financing, and so forth.

A scheme that addresses this issue is the Medici Fellowship Scheme. The initial pilot scheme provided for 50 fellowships over a two-year period. The focus originally was on the commercialization of biomedical research in five Midlands universities. Fellows are required to have significant prior (typically postdoctoral) research. Local training is provided in the host institution in finance, marketing, intellectual property rights, and business strategy. Fellows are encouraged to develop links with practitioners from the biotech business community, technology-transfer organizations, the legal and regulatory professions, and finance providers.

Regional Funds for the Development of Spinoffs

The difficulties in obtaining funding for early-stage ventures are well recognized, and spinoffs from universities pose particular problems in this respect (Wright, Lockett, and others 2006). As part of an attempt to address this issue, specific regional funds have been established to help fund spinoffs and other related entrepreneurial activities.

For example, the Lachesis Fund was established in 2002 with a £3 million award from the University Challenge Initiative sponsored by the Office of Science and Technology. The aim of the fund is to provide important next-step funding beyond Innovation Fellowship support when a spinoff is likely. At the end of 2005, the fund had become a £7.65 million seed fund linked to five East Midlands universities covering 98 percent of the research base.

A second example is Biofusion, a fund that was also established in 2002. The fund was intended to provide financing to academic scientists to commercialize their intellectual property and also to facilitate the introduction of start-up management skills. By the end of 2005, Biofusion had funded eight spinoffs. Biofusion floated itself on the Alternative

Investment Market in 2005 and raised £8 million. The University of Sheffield is a significant owner, and Biofusion has a 10-year exclusive agreement with the university to develop biotech and related inventions.

Graduate and Researcher Education and Mobility

A major issue for many regions, especially peripheral ones, is the drain of graduates to more central regions. In part, this "brain drain" may arise from a lack of awareness by graduates and researchers of the opportunities that are available in a particular region. As large firms are typically more organized and have greater resources than local small and medium enterprises, this issue may be especially acute for the smaller firms. Accordingly, some schemes have been developed at local and regional levels to address this mobility issue.

An example of such a scheme is the Graduate Employability Programme, introduced by the South Yorkshire Business Enterprise Network. The scheme provides business training for graduates in biotech. The training involves an eight-week focused workshop and subsidization of 50 percent of salary costs for a period of six months. The scheme also involves sponsor companies, although such companies are recruited to provide site visits and presentations rather than financial commitment.

A second example is the development by BioScience YES–Yorkshire and Humber of the Young Entrepreneurs Scheme. This scheme is intended for postgraduate and postdoctoral scientists at universities in the region. The aim is to raise awareness of commercialization possibilities by helping participants to devise a business plan, which is then presented to a panel of experts.

A further scheme to encourage graduate recruitment and retention in a particular region was developed by Yorkshire Forward in response to the loss of graduates from the Yorkshire region. Graduates Yorkshire has been funded since 2002 to deliver a Web site matching service, called Graduate Link, to help businesses recruit graduates to prevent them from leaving the region. The scheme particularly targets jobs requiring high-level skills. The Web site contains vacancies within region and by sector.

Education and Network Schemes

A final set of university-industry initiatives comprises education and network schemes. The Science and Enterprise Challenge scheme provided central government funding, supplemented by RDA funding, to develop entrepreneurship education both inside and outside universities. Within universities, the aim was to develop entrepreneurship education across institutions, from the undergraduate to the faculty level. In addition, the scheme was intended to develop networks between universities and entrepreneurs.

For example, the University of Nottingham Institute for Enterprise and Innovation (UNIEI) was established under the Science Enterprise Challenge scheme. UNIEI has developed a range of interventions, including courses for undergraduates, postgraduates, and faculty; laboratory facilities to enable opportunities for new ventures to be developed; and, for entrepreneurs, master classes covering topics such as developing new ventures.

Effects of University-Industry Initiatives

The previous sections illustrated the effects of particular regional university-industry schemes. In this section, more general evidence on their influence is represented. Although some schemes are relatively new, initial evaluations do permit useful insights regarding their effects.

The outcomes of the HEROBC Scheme in the East Midlands included increased awareness of the scope for commercialization (University of Nottingham, Loughborough University, and University of Leicester 2004). More concretely, the initiative supported 9 spinoffs and 15 license opportunities. Those developments have involved the securing of £908,000 of seed capital and industry funding. In addition, the funding facilitated academic engagement with 60 businesses. The resulting portfolio of projects secured £2.3 million in matched, follow-on funding.

An evaluation of the Medici Fellowship Scheme in 2005 showed that it provided key skills and that fellows subsequently exhibited entrepreneurial behavior in host schools (Mosey and others 2005). The principal benefit to the schools in which the scheme was introduced involved raising awareness of various other schemes and training courses to promote commercialization. In a comparison of initiatives, 59 percent of survey participants reported that the Medici Fellowship Scheme had the most important effect on licensing, and 77 percent of respondents reported that it had the most important effect on spinoff activity. The fellows identified these main benefits:

- Receiving encouragement to exploit intellectual property generated from their research
- Receiving access to market information
- Working with other higher education or research institutes
- Gaining access to potential firms
- Working with other departments within the university
- Gaining access to potential customers
- Having available proof-of-concept funding

More problematic was the ability to obtain funding from business angels and to attract commercial management to spinoffs. Participants identified the scheme as having the most effect on (a) raising awareness of intellectual property funding within the academic network (21 percent of respondents), (b) creating an ability to conduct early-stage market research (18 percent), and (c) identifying undiscovered or undeveloped intellectual property and raising funding and writing business plans (14 percent).

Some of the main shortcomings and areas for improvement identified included the need for more fellows over a longer period of time, the need for consistency of training across universities, the need for the scheme to be expanded to other disciplines outside the medical and life sciences, the need to enhance the entrepreneurial behavior skills of fellows, the need to disseminate knowledge acquired more widely, and the need to develop a more defined career path for fellows. The scheme has now been extended to 15 universities and provides more than 100 fellowships.

Analysis of the effects of the 12 Science Enterprise Challenge (SEC) funds, located in universities across the United Kingdom, shows that, with respect to both postgraduate and undergraduate training, most recipients of SEC funds exceeded their targets (table 9.1). Moreover, most recipients have been able to effect a major positive change (SQW Economic Development Consultants 2005). Nine of the funds recorded creation of spinoffs, and five applied for patents, though only three granted licenses. SQW Economic Development Consultants (2005) noted that only four of the funds reported new business links, but in all but one case, this achievement equaled or exceeded targets.

The 19 University Challenge Initiative funds (all but two of which are partnerships involving between two and six universities) show that from January 1998 to July 2003, 413 projects were funded, of which 103 received cofunding. At £59.2 million, this cofunding considerably exceeded the £36.3 million in funding received from the initiative (SQW Economic

Table 9.1. Cumulative Effects of Science Enterprise Challenge and University Challenge Initiative Funds

Effect	*Science Enterprise Challenge*	*University Challenge Initiative*
Number of patent applications	103	278
Number of patents granted	8	28
Number of license agreements	0	18
Income from licensing intellectual property (£ million)	2.9	5.1
Number of spinoffs	268	213
Business representation on governing bodies	49	4
Income from businesses (£ million)	1.0	0
Number of science, engineering, and technology students receiving enterprise training	1,467	0
Number of other students receiving enterprise training	38,469	0

Source: Adapted from SQW Economic Development Consultants 2005, table 8.6.

Development Consultants 2005). However, cofunding is skewed toward a small number of projects. SQW Economic Development Consultants (2005) noted that University Challenge Initiative funding has reduced pressure on universities to establish companies earlier than optimal, thereby helping to create better-quality spinoffs. Only one fund surveyed by SQW Economic Development Consultants considered it realistic that returns on investments would cover the cost of investment and generate a surplus for future investment. The reasons for this relatively poor performance are that (a) the funds are not large enough to become self-sustaining and (b) the amount that can be invested in any one project is restricted. Hence, ownership and returns in highly successful projects are likely to be diluted after subsequent rounds of financing.

Conclusions and Issues

As this chapter shows, a number of schemes and initiatives have been developed at the regional and local levels to stimulate and sustain university-industry links. These schemes have embraced a range of potential areas in which such links can be stimulating, including support for

- Collaborative research and innovation
- Development of incubation centers and enterprise hubs
- Long-term research partnerships

- Recruitment and development of fellows to facilitate technology and knowledge transfer
- Spinoff ventures and licensing
- Graduate and researcher mobility
- Education and networking schemes

Nevertheless, a number of issues remain. First, in the United Kingdom, much of the development of initiatives at local and regional level has been the result of initiatives taken at a national level. As noted earlier, RDAs are the central mechanism for promoting university-industry links. However, as yet, few RDAs provide an integrated set of initiatives. Some are making significant progress, as seen in Yorkshire. There may be scope for other RDAs to learn from such developments.

Second, there appears to be a need to identify more clearly the demand- and supply-side dimensions of collaboration. For example, an important issue concerns the identification of the different kinds of customers for universities' outputs. Such an approach requires some notion of the kinds of activities in which universities have a comparative advantage over provision of services from outside a university.

Third, it may be important to devote explicit attention to market segmentation in terms of which universities within a region or locality are most suited to deliver certain types of links with industry. This market segmentation approach may enable better matches to be made between the range of knowledge- and technology-transfer activities that universities offer and the different types of local industry that they can serve. Large and small firms locally may have very different requirements. In particular, large companies are unlikely to be motivated to work with a university just because of proximity; however, they may be attracted to work with a university if it has a reputation for world-class research and critical mass in an area. Hence, universities need to build areas of expertise that locally based large firms will want to access. Small firms often need routine business management and financial skills. For the majority of new small firms, it is not clear that a university has a comparative advantage in the provision of such expertise. However, there may be scope to develop this activity in an integrated way if these firms can spin out technology from the university. The Medici Fellowship Scheme is one potential route.

Fourth, it is also important to consider the benefits for universities and academic scientists from collaboration with local industry, rather than to focus solely on the benefits to industry. This point raises issues concerning the objectives and incentives for universities and academics. For universities, mechanisms to resolve conflicts with their goal to be nationally and internationally recognized may need to be developed. For academics, conflicts with the need for publication in leading scientific journals to gain career progression or recognition in national research assessment exercises may need to be resolved. In an environment of constrained research funding from national research councils, funding from industry may have its attractions.

A fifth and related issue concerns the focal point for university-industry links within universities. For example, to what extent are links likely to be most attractive and feasible for top or middle-range research? Top researchers may have particular interest in world-leading innovative companies, but they may be able to obtain sufficient research funding from the national funding councils. Middle-range researchers, who may experience greater difficulty in obtaining research council funding, may find research funding from industry attractive.

Sixth, development of links is closely associated with development of relationships, which may take a considerable period to establish and may rely on development of personal contacts by individual academics. Therefore, initiatives should acknowledge the temporal dimension associated with supporting the development of university-industry links.

Finally, the nature of university-industry links may depend on the nature of the region (core, peripheral, and so forth) in which a university is embedded. In more peripheral regions, some scope may exist for consideration of regional cooperation among universities to create critical mass in certain areas. Universities in developing regions might face greater difficulties in establishing links with local industry. Equally, universities in regions that are facing decreasing economic activity might face a difficult situation, which could be exacerbated by leakage of knowledge and graduate mobility to more dynamic regions. Universities in more mature regions may need to develop graduate programs that more closely match the emerging needs of the region or that are compatible with policies to regenerate regions.

References

Her Majesty's Treasury. 2004. *Science and Innovation Investment Framework 2004–2014: Next Steps*. London: Her Majesty's Stationery Office.

Lambert, Richard. 2003. *Lambert Review of Business-University Collaboration*. London: Her Majesty's Stationery Office.

Mosey, Simon, Andy Lockett, Paul Westhead, and Tracey Hassall-Jones. 2005. *Evaluation of the Medici Fellowship Scheme: Final Report*. Nottingham, U.K.: Nottingham University Business School Institute for Enterprise and Innovation.

SQW Economic Development Consultants. 2005. *Interim Evaluation of Knowledge Transfer Programmes Funded by the Office of Science and Technology through the Science Budget*. Cambridge, U.K.: SQW Economic Development Consultants.

University of Nottingham, Loughborough University, and University of Leicester. 2004. *Final Report to HEFCE: Higher Education Reach-Out to Business and the Community*. University of Nottingham, Loughborough University, and University of Leicester.

Wright, Mike, Bart Clarysse, Andy Lockett, and Nathalie Moray. 2006. *University-Industry Linkages: Evidence from Mid-Range Universities in Europe*. Washington, DC: World Bank.

Wright, Mike, Andy Lockett, Bart Clarysse, and Martin Binks. 2006. "University Spin-Out Companies and Venture Capital." *Research Policy* 35 (4): 481–501.

CHAPTER 10

University-Industry Research Collaboration and Technology Transfer in the United States since 1980

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Although the topic has received considerable attention from scholars, university administrators, industrial managers, and policy makers since 1980, university-industry collaboration in U.S. research universities has a long history, spanning the 20th century. Much of the discussion since 1980 has focused on university patenting and licensing of inventions as a means to support collaboration and university-industry technology transfer. But research collaborations between U.S. university and industrial researchers have relied on many channels of technology and knowledge exchange, including publishing, training of industrial researchers, faculty consulting, and other activities. Indeed, activities other than patenting appear to have been at least as important as the patenting and licensing activities of U.S. universities and their faculties for most of the past century.

Many recent studies based on interviews and surveys of senior managers in industries ranging from pharmaceuticals to electrical equipment have examined the influence of university research on industrial innovation. All these studies (Cohen, Nelson, and Walsh 2002; GUIRR 1991; Levin and others 1987; Mansfield 1991) emphasize the significance of interindustry differences in the relationship between university and industrial innovation. The biomedical sector—especially biotechnology and pharmaceuticals—is unusual in that advances in university research affect industrial innovation more significantly and directly in this field than in other sectors. The studies also suggest that academic research rarely produces prototypes of inventions for development and commercialization by industry; instead, academic research informs the methods and disciplines applied by firms in their research and development (R&D) facilities. Finally, the channels rated by industrial R&D managers as most important in the interaction between academic and industrial innovation include patents and licenses only in the biomedical sciences. Different channels (such as faculty consulting) are given greater weight in other fields.

Despite those research results, a number of the U.S. universities that established patent-licensing programs during the 1980s and 1990s emphasized patenting and licensing of faculty research results as the most important channel for technology transfer and research collaboration, as well as for revenues. More recently, however, there is evidence of change in the technology-transfer strategies of leading U.S. universities. Patenting and licensing strategies at the University of California, Berkeley, and Stanford University, for example, now are more closely integrated with other policies that seek to establish research relationships with industrial firms, as well as increase industry-funded research. Some universities also have begun to differentiate between biomedical research and other fields of research in managing their patent activities. Simultaneously, many U.S. industrial firms—especially those in the information technology industries—have criticized university patenting and licensing policies as obstacles to collaboration. In some cases, U.S. firms have cited the less aggressive policies of foreign universities as a reason to shift at least some of their sponsored academic research to those campuses. Such criticism and the (implicit) threat of foreign competition have also played a role in the shifting policies of U.S. research universities.

Historical Overview

University-industry collaboration in U.S. higher education was facilitated by the unusual structure of the higher education system (especially by comparison with the systems of other industrial economies) during the 20th century. The U.S. system was significantly larger; included a very heterogeneous collection of institutions (religious and secular, public and private, large and small, and so on); lacked any centralized national administrative control; and encouraged considerable interinstitutional competition for students, faculty, resources, and prestige (see Geiger 1986, 1993; Trow 1979, 1991, among other discussions). In addition, the reliance by many public universities on local (state-level) sources for political and financial support further enhanced their incentives to develop collaborative relationships with regional industrial and agricultural establishments. The structure of the U.S. higher education system thus strengthened incentives for faculty and academic administrators to collaborate in research and other activities with industry—and to do so through channels that included much more than patenting and licensing.

Despite the adoption by a growing number of universities of formal patent policies by the 1950s, many of these policies, especially at medical schools, prohibited the patenting of inventions, and university patenting was less widespread than after 1980. Moreover, many universities chose not to manage patenting and licensing themselves. The Research Corporation, founded by Frederick Cottrell, a University of California (UC) faculty inventor who wished to use the licensing revenues from his patents to support scientific research, assumed a prominent role as a manager of university patents and licensing during the 1950s and 1960s. Even in the earliest decades of patenting and licensing, however, biomedical technologies accounted for a disproportionate share of licensing revenues for the Research Corporation and other early university licensers, such as the Wisconsin Alumni Research Foundation.

The number of universities that established technology-transfer offices or hired technology-transfer officers began to grow in the late 1960s, well before the passage of the Bayh-Dole Act of 1980. The 1970s, as much as or more than the 1980s, were a watershed in the growth of U.S. university patenting and licensing. U.S. universities expanded their patenting, especially in biomedical fields, and assumed a more prominent role in managing their patenting and licensing activities, thereby supplanting the Research Corporation. Agreements between government research funding agencies and universities contributed to the growth of patenting during the 1970s. Private universities also expanded their patenting and licensing during that decade.

Stagnation in federal academic support during the 1970s, in addition to creating interest in patenting, also led universities to seek industrial support for their research.[1] From 1970 to 1980, the industry share of total funding for academic research increased from 2.7 percent to 4.1 percent (National Science Board 2006, appendix table 4-5), and by 1999 had reached 7.4 percent, from which it declined to 7 percent in 2005. Note that this level is well below the 11 percent of university research funded by U.S. industry in 1953. Cohen, Florida, and Goe (1994) point out that more than half of the 1,056 university-industry research centers covered by their survey were established during the 1980s, largely as a result of university initiatives. These centers accounted for more than US$2.5 billion in R&D spending on academic campuses in 1990.

The Bayh-Dole Act of 1980

The Bayh-Dole Patent and Trademark Amendments Act of 1980 provided blanket permission for performers of federally funded research to file for patents on the results of such research and to grant licenses for those patents (including exclusive licenses) to other parties. Lobbying by U.S. research universities was one of several factors behind the passage of the Bayh-Dole Act.

The act facilitated university patenting and licensing in at least three ways. First, it replaced a web of institutional patent agreements that had been negotiated between individual universities and federal agencies with a uniform policy. Second, its provisions expressed congressional support for the negotiation of exclusive licenses between universities and industrial firms for the results of federally funded research. Third, it reduced the power of federal funding agencies to oversee the terms of licensing agreements between research performers and licensees.

Although the act reduced federal funding agencies' oversight of the specific terms of licensing contracts for patented inventions that result from publicly funded research, three provisions of the act affect the ownership and licensing of this intellectual property. Federal funding agencies retained a nonexclusive, royalty-free license for all patents resulting from public funding and assigned to research performers. Federal agencies are empowered to deny patent rights to a non-U.S. research performer and to deny patent rights in circumstances under which denial of ownership of the invention will advance the goals of the act. As Rai and Eisenberg (2003) point out, denial of patent rights to a contractor is subject to an

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[1] The survey of university-industry research centers compiled by Cohen and others (1998, 183) found that 73 percent of these centers, all of which enlisted significant industry funding for their operations, were established at the impetus of the universities.

elaborate process of appeal that extends to the U.S. Court of Federal Claims; they cite only one instance in which patent rights have been denied to a contractor under this provision. Finally, the act grants "march-in" rights to federal agencies, enabling a federal agency to mandate licensing of a patent if the patentholder or its licensee are not exercising due diligence in the development of the invention. This provision also includes procedures for administrative and judicial appeals, but the power has yet to be exercised by a federal funding agency.[2]

The passage of the Bayh-Dole Act was one part of a broader shift in U.S. policy toward stronger intellectual property rights.[3] Among the most important of such policy initiatives was the establishment of the U.S. Court of Appeals for the Federal Circuit in 1982. Established to serve as the court of final appeal for patent cases throughout the federal judiciary, it soon emerged as a strong champion of patentholder rights.[4] But even before the establishment of the court of appeals, the 1980 U.S. Supreme Court decision in *Diamond v. Chakrabarty* upheld the validity of a broad patent in the new industry of biotechnology, thereby facilitating the patenting and licensing of inventions in this sector. The effects of the act thus must be viewed in the context of this larger shift in U.S. policy on intellectual property rights.

Effects of the Bayh-Dole Act

A number of scholars have documented the role of the Bayh-Dole Act in the growth of patenting and licensing by universities since 1980 (Henderson, Jaffe, and Trajtenberg 1998). But it is properly viewed as initiating the latest, rather than the first, phase in the history of U.S. university patenting. This latest phase is characterized by a higher level of direct involvement by universities in the management of their patenting and licensing activities, in contrast to the reluctance of many U.S. universities to become directly involved in patenting before the 1970s.

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[2] In 1997, Cell Pro attempted to compel the National Institutes of Health to exercise the march-in rights and require licensing by Johns Hopkins University of a patent with broad claims to bone-marrow stem cell technology, a patent then licensed exclusively by Baxter Healthcare. Cell Pro's petition was denied, and the firm eventually filed for bankruptcy (Bar-Shalom and Cook-Deegan 2002; McGarey and Levey 1999).

[3] According to Katz and Ordover (1990), at least 14 congressional bills passed during the 1980s focused on strengthening domestic and international protection for intellectual property rights. The U.S. Court of Appeals for the Federal Circuit has upheld patent rights in roughly 80 percent of the cases argued before it, a considerable increase from the pre-1982 rate of 30 percent for the federal bench.

[4] See Hall and Ziedonis (2001) for an analysis of the effects of the U.S. Court of Appeals for the Federal Circuit and related policy shifts on patenting in the U.S. semiconductor industry.

Keeping in mind that we cannot separate the effects of the Bayh-Dole Act from those of other influences, how has U.S. university patenting changed since 1980? Universities increased their share of patenting from less than 0.3 percent in 1963 to nearly 4 percent by 1999, but the rate of growth in this share began to accelerate before rather than after 1980. Another issue of interest is the distribution among technology fields of university patents before and after the act was passed. University patents in fields other than biomedicine increased by 90 percent from the 1968–70 period to the 1978–80 period, but their biomedical patents increased by 295 percent. The increased share of funding for the biomedical disciplines within overall federal funding of academic R&D, the dramatic advances in biomedical science that occurred during the 1960s and 1970s, and the strong industrial interest in the results of this biomedical research all affected the growth of university patenting during this period.

The Bayh-Dole Act generated a wave of entry by universities into the management of patenting and licensing, although growth in these activities was already well established by the late 1970s. The share of U.S. research university patenting accounted for by institutions with at least 10 patents issued before 1980 declined from more than 85 percent during 1975 to 1980 to less than 65 percent by 1992. By contrast, low-intensity pre-1980 patenters (institutions with fewer than 10 patents) increased their share of all academic patents from 15 percent in 1981 to almost 30 percent in 1992. And institutions with no patenting activity during 1975 to 1980 increased their share of overall academic patenting from zero in 1980 to more than 6 percent by 1992. Our analysis of change in the average importance of university patents after the Bayh-Dole Act suggests that less experienced entrant universities received fewer significant patents in the immediate aftermath of the act's passage. However, the gap between the quality of their patents and those of experienced institutional patenters narrowed by the end of the 1980s. This point is important, because it suggests that patenting strategies, especially for entrant universities, changed over the course of the 1980s toward a more selective approach. Patenting strategies at some research universities appear to be undergoing change once again.

This evidence concerning the relatively low quality of the early patents obtained by many entrant institutions also underscores the need for caution in using counts of patents (on their own or relative to R&D spending) as a measure of the productivity of research universities. Patents vary widely in quality: like academic papers, a great many patents are never cited or actively worked by anyone, and the value of any portfolio of patents typically is dominated by a very small number of patents. Comparisons of patent productivity across universities or (even more questionable) between universities and industry must incorporate some adjustment for the quality of patents, for example, through citation-weighting of patents.[5]

Evidence cited in Mowery and others (2004) reveals that gross licensing revenues for Columbia University, Stanford University, and the UC system were dominated by a small number of patents. For each university, the top five patents accounted for more than 65 of gross licensing revenues. The top five patents were mainly biomedical inventions. Universities that lack a major biomedical research program may not produce such “home run” patents and therefore may reap lower gross revenues. The high costs of establishing and operating technology licensing offices (costs that include the legal expenses associated with patent prosecution and litigation) also depress net revenues.

Even the UC system (which consisted of nine campuses during the period covered by these data), one of the leading U.S. university recipients of licensing revenue during the era following passage of the Bayh-Dole Act, reaped surprisingly small net revenues from licensing activities. During fiscal years 2001 to 2004, average annual gross licensing revenues for the UC system were roughly US$75 million. The net contribution to UC operating expenses, however, a figure that subtracts the operating expenses of the technology licensing office and payments to the faculty inventor, averaged slightly more than US$15 million annually. This amount represents a small fraction (less than 1 percent) of the annual research budget for the UC system of more than US$3 billion. Industry funding of academic research within the UC system in fiscal year 2001 (the most recent year for which comprehensive data are available) amounted to US$235 million, dwarfing both the average gross and the net institutional revenues associated with licensing activities.[6]

Revenues are, of course, not the only motive for university licensing activities. Other important motives include the retention of faculty members who wish to see their inventions patented and licensed, the transfer of university inventions to commercialization, and regional or state-level

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[5] More generally, comparisons of the cost-effectiveness of R&D investments in universities and industry that rely on patents produced per R&D investment dollar are hazardous guides for policy. Such comparisons ignore the fact that research universities and industrial R&D performers pursue fundamentally different though complementary missions that yield different outputs.

[6] See http://www.ucop.edu/research/publications/pdf/resfund01.pdf for more information.

economic development. In the wake of the 2003 *Madey v. Duke* decision of the Court of Appeals for the Federal Circuit, which eliminated the informal "experimental use" defense against claims of patent infringement, another important motive is the preservation of the freedom of academic scientists to conduct research. This array of potential goals for patenting and licensing activities, however, creates some challenges for management. First, these goals are not entirely compatible. For example, support for regional economic development may entail an acceptance of lower royalty rates on licenses for firms that are active in the vicinity of the university. Technology licensing thus will involve some trade-offs among these goals. Second, despite these trade-offs, as well as the evidence above on the relatively modest scale of net revenues at many university technology licensing offices, a recent survey of technology licensing officers (Jensen and Thursby 2001) indicates that individuals surveyed cite licensing revenues as the most important goal of their activities.

Developments in University-Industry Relationships since 1995

Since 1995, several aspects of the management by U.S. universities of their relationships with industry have changed. A number of universities have expanded their equity investments in licensee firms as a means of profiting from faculty inventions. In addition, several of the leading U.S. research universities have revised their policies on technology licensing, placing greater emphasis on licensing as one component of a broader set of relationships (and support for academic research) with industry. Finally, a number of large U.S. firms have expressed strong criticism of the intellectual property and technology licensing policies of U.S. universities, leading to still further changes in the policies of several U.S. universities.

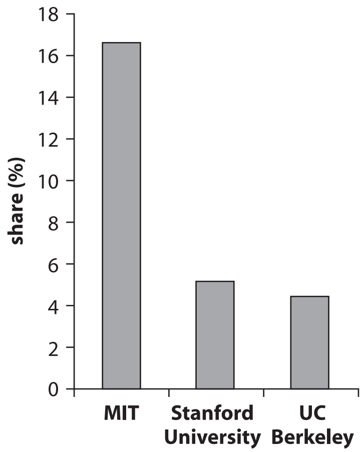
University Equity Investments in Licensees An important development in the way many U.S. universities manage their patenting and licensing activities was an increase during the 1990s in their acquisition of equity stakes in small-firm licensees. In many cases, university licensing officers believe that equity positions may provide a larger upside potential than a licensing contract alone, especially for a small firm with little if any cash flow. The limited financial resources of start-up licensees also mean that universities may accept equity stakes in lieu of licensing fees or other upfront payments. The fiscal year 2002 survey by the Association of University Technology Managers (AUTM 2003) reports that 443 licenses negotiated during that year included the grant to licenser universities of equity in the licensee firm. Of these 443 licenses, 313 were negotiated with new firms founded specifically to commercialize the university invention. The 443 licenses with equity represented an increase over fiscal year 2001 of almost 52. Interestingly, the share of licenses with equity that were negotiated with existing small firms nearly tripled during 2002 (from 43 to 130), an increase that the survey analysis interpreted as an indication of increased financial pressures on these small-firm licensees.

Developments at MIT, Stanford, and UC Berkeley The Massachusetts Institute of Technology (MIT), Stanford, and UC Berkeley share a number of characteristics. All have engineering colleges ranked among the top five in the United States, as well as strong research capabilities in the physical sciences, and all have long permitted patenting by faculty members. All also have a history, dating back to the early 20th century, of collaborative relationships with industry that have contributed to the growth of regional information technology, electronics, and biomedical industrial complexes in northern California and eastern Massachusetts.

There are also significant contrasts among the three institutions. Only Stanford has a research-intensive medical school that has been an important source of licensed inventions. Since 1970, the university has managed patenting and licensing directly; previously it used the Research Corporation for those activities. MIT similarly reduced its reliance on the Research Corporation in the early 1960s, partly as a result of disputes over licensing policy (see Mowery and Sampat 2001), and has managed its patenting and licensing activity through its Technology Licensing Office since the late 1960s. The UC system has managed patenting and licensing since the 1940s, but the systemwide Office of Technology Transfer was strengthened and expanded in the 1970s. Since 1990, UC Berkeley has operated a campus-level technology licensing office, which shares responsibility for managing patenting and licensing activities with the systemwide office.

All three universities have a diverse array of programs to support collaborations with industry. For example, all three universities' colleges of engineering operate industrial liaison programs that offer memberships to firms, for a fee, that allow firm employees to review research advances, visit campus laboratories, and participate in regular meetings with researchers. Also, depending on the structure of the particular program and the size of the annual fee paid by the firm, such programs may include opportunities for firm employees to work temporarily in academic research

Figure 10.1. Industry-Funded Share of R&D: MIT, Stanford, and UC Berkeley, Fiscal Year 2003



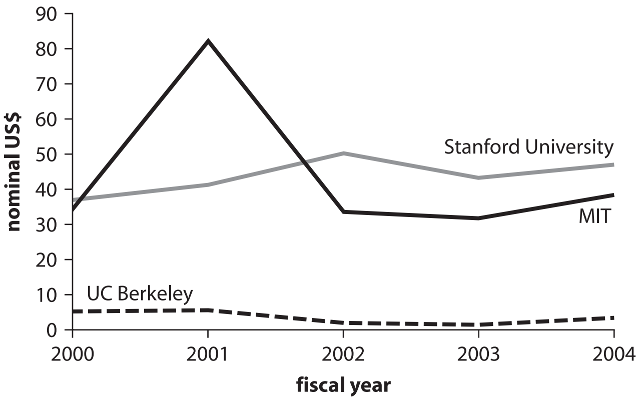
Source: http://www.nsf.gov/statistics/nsf05320/tables/table29.xls.

facilities. All three universities also promote opportunities for industrial firms to support individual faculty research projects. Interestingly, however, the levels of industry-supported research differ significantly among the three institutions, which have roughly similar research budgets (ranging in fiscal year 2003 from US$486 million for MIT to US$507 million for UC Berkeley and US$603 million for Stanford). As figure 10.1 shows, industry sources funded 16 percent of MIT campus research in fiscal year 2003—more than twice the average for all U.S. universities (roughly 7.4 percent)—but accounted for a substantially smaller share of the research budgets of UC Berkeley (4.4 percent) and Stanford (5.2 percent).

Additional comparative data on invention disclosures and licensing activity are displayed in figures 10.2, 10.3, and 10.4. The contrasts between UC Berkeley and the two private research universities, MIT and Stanford, are striking. Gross licensing income (which included some large cashouts of equity investments by the MIT and Stanford licensing offices in fiscal years 2000 and 2001)[7] is substantially higher at both MIT

[7] All three universities' technology licensing programs are allowed to accept equity in start-up licensees in lieu of patent prosecution costs or licensing fees. Only Stanford reports the annual number of transactions involving its acquisition of equity in licensees. In fiscal years 2000 and 2001, MIT realized equity-based gains of US$14.5 million and US$55.6 million (included in the data depicted in figure 10.2). Stanford's Office of Technology Licensing reported an equity-based profit of US$2.1 million in fiscal year 2001 and US$336 million in fiscal year 2005 (this bonanza was associated with the sale of its equity stake in Google).

Figure 10.2. Gross Licensing Royalties, Fiscal Years 2000–04



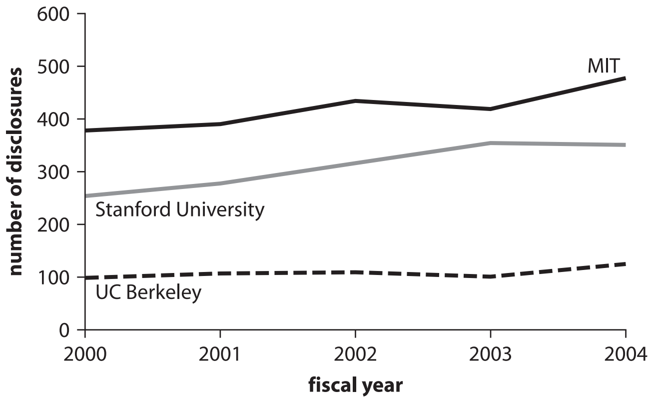
Sources: MIT: http://web.mit.edu/tlo/www/about/office_statistics.html; Stanford University: http://otl.stanford.edu/about/resources.html; UC Berkeley: http://www.ucop.edu/ott/genresources/annualrpts.html.

and Stanford than at UC Berkeley. Indeed, the licensing activities of the UC Berkeley Office of Technology Licensing yielded average annual net revenues to the campus of slightly more than US$1 million after the deduction of operating expenses and payments to the inventor, during fiscal years 2001 to 2004.

Some of these differences reflect the fact that the UC Berkeley Office of Technology Licensing was more recently established and has a smaller patent and license portfolio than the offices of the other two universities. (Licensing income associated with patents issued before the 1990 creation of the UC Berkeley office flows to the systemwide licensing office.) But figures 10.3 and 10.4 show that the number of annual invention disclosures and licensing agreements also are much higher at MIT and Stanford than at UC Berkeley, suggesting that the wide gap in gross licensing income between UC Berkeley and the other two institutions is not likely to vanish with the passage of time. The purely financial institutional benefits of patenting and licensing for UC Berkeley thus are modest, albeit positive, and are much smaller than those flowing to MIT or Stanford. Nonetheless, only Stanford's average gross licensing income (netting out equity cashouts) during 2001 to 2004 exceeds its fiscal year 2003 level of industry-funded research.[8]

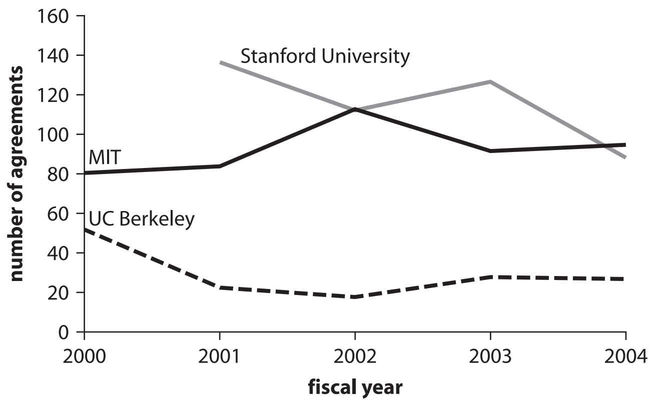
[8] National Science Foundation data (http://www.nsf.gov/statistics/nsf05320/tables/table29.xls) indicate that in fiscal year 2003 industry-funded research amounted to US$31 million at Stanford, US$22 million at UC Berkeley, and US$81 million at MIT.

Figure 10.3. Annual Invention Disclosures, Fiscal Years 2000–04



Sources: MIT: http://web.mit.edu/tlo/www/about/office_statistics.html; Stanford University: http://otl.stanford.edu/about/resources.html; UC Berkeley: http://www.ucop.edu/ott/genresources/annualrpts.html.

Figure 10.4. Licensing Agreements, Fiscal Years 2000–04



Sources: MIT: http://web.mit.edu/tlo/www/about/office_statistics.html; Stanford University: http://otl.stanford.edu/about/resources.html; UC Berkeley: http://www.ucop.edu/ott/genresources/annualrpts.html.

Although the patenting and licensing activities of all three universities are profitable on a net institutional income basis, all three now manage their licensing activities to complement broader programs that promote closer research relationships with industry. For example, the director of the Stanford Office of Technology Licensing also oversees the university's Industrial Contracts Office, which manages sponsored-research agreements with industry, as well as oversees material transfer agreements, which govern the transfer among researchers of research tools and materials. Industrial firms that support campus research can receive licenses (in some cases, royalty-free licenses) for the results of this research.

A similar trade-off between maximizing licensing revenues and obtaining industry research funding is apparent in the creation in 2003 of the Office of Intellectual Property and Industry Research Alliances at UC Berkeley, which absorbed the established Office of Technology Licensing and a newer Industry Alliances Office, which was charged with overseeing the negotiation of sponsored-research agreements with industry. Moreover, the UC Berkeley licensing office, along with other UC technology licensing offices, has implemented a new policy that recognizes the differences among industries in the value (and likely licensing income) of patents in different fields of research. In 2000, the UC President's Office authorized the negotiation of royalty-free licenses with industrial sponsors of campus research in electrical engineering and computer science. Another reflection of the changing priority assigned to licensing royalties relative to other goals at UC Berkeley is the socially responsible licensing initiative, which negotiates royalty-free licenses on inventions sold in low-income economies.[9]

The economic significance of these shifts in licensing strategy and policy is difficult to evaluate, and their implementation also raises challenges. Very few academic laboratories strictly separate research activities according to funding sources. The vast majority of such research is financed by the federal government. Policies that seek to differentiate licensing terms on the basis of source of funding may prove to be infeasible. Similarly, the development and implementation of policies that promote differences in licensing terms according to characteristics of end-user markets will be difficult for the many inventions that serve both high- and low-income markets. Nonetheless, these initiatives, along

[9] Yet another initiative of note on the UC Berkeley campus was the 1998 research agreement between the Novartis Corporation and the campus's Plant and Microbial Biology Department. The agreement involved the contribution by Novartis of US$25 million to support the department's research over a five-year period. In exchange, Novartis was granted rights to review all department invention disclosures and exercise an option to negotiate a license to a share of these disclosures proportionate to its share of overall department research funding (roughly one-third). The initiative was controversial, in part because of excessive secrecy in its negotiation and poor handling by campus administrators of its announcement, and Novartis elected not to renew the agreement. As of 2002, the firm had exercised its option on two of the department's disclosures, although the status of license negotiations is unclear. Given the controversy surrounding this undertaking, it seems unlikely that anything similar will be negotiated by UC Berkeley officials in the near future.

with the assignment of responsibility for a broader set of relationships with industry to campus directors of technology licensing offices at both Stanford and UC Berkeley, suggest that even these leading academic licensers are developing a more nuanced approach to the management of trade-offs within their technology-transfer strategies.

Industry Criticism of U.S. University Licensing Policies and Practices

Since 1980, the growth in U.S. university patenting and (to an even greater degree) licensing was dominated by the biomedical sciences, in which patents have considerable economic value and the number of patents associated with significant commercial innovations (for example, a new pharmaceutical product) often is smaller than that associated with commercial innovations in fields such as information technology. In at least some of the fields outside biomedicine, anecdotal evidence suggests that the efforts of many universities to seek patent licensing income have been a source of friction, rather than a facilitator of collaboration, with industry. Dr. R. Stanley Williams of Hewlett Packard, a firm with a long history of close research collaboration with U.S. universities, stated in testimony before the U.S. Senate Commerce Committee's Subcommittee on Science, Technology, and Space that

> Largely as a result of the lack of federal funding for research, American universities have become extremely aggressive in their attempts to raise funding from large corporations. . . . Large U.S.-based corporations have become so disheartened and disgusted with the situation they are now working with foreign universities, especially the elite institutions in France, Russia, and China, which are more than willing to offer extremely favorable intellectual property terms. (September 17, 2002; http://www.memagazine.org/contents/current/webonly/webex319.html).

In the biomedical field, the National Institutes of Health director's Working Group on Research Tools stated in its report that

> If there was one point on which virtually every private firm that we spoke to was in agreement, it was that universities take inconsistent positions on fair terms of access to research tools depend-

> ing on whether they are importing tools or exporting them. Over and over again, firms complained to us that universities "wear the mortarboard" when they seek access to tools developed by others, yet they impose the same sorts of restrictions when they enter into agreements to give firms access to their own tools. As one lawyer for a small biotechnology firm put it, "Universities want it both ways. They want to be commercial institutions when it comes to licensing their technology, but to be academic environments when it comes to accessing technology that others have developed. . . . They throw the same things in the way of small companies." (NIH 1998, 15)

A more sweeping (and arguably exaggerated) assessment was presented at a 2003 conference organized by the Government-University-Industry Research Roundtable (GUIRR) at the National Academy of Sciences:

> [T]he universities' approach of securing iron-clad protection for intellectual property seems to be yielding diminishing returns, even within the narrow confines of the licensing activity itself. . . . The requisite legal negotiations for IP-that-will-ultimately-prove-to-be-useless are laborious, individualized, and negotiated between universities and companies on a case-by-case basis. The up-front legal negotiations can easily cost more than the total cost of the research project being conducted, and/or extend past the time when the company has interest in the technology path being pursued. . . . In summary, the uncertainty of the true value of university-generated intellectual property, combined with a litigious culture, have [made] the university-industry working relationship—one that has historically contributed greatly to graduate education—unaffordable and nearly unsustainable within the U.S. (GUIRR 2003, 2).

These critical comments have triggered considerable discussion between large industrial firms (many of which are in the information technology sector) and U.S. research universities over intellectual property policies and licensing guidelines. In December 2005, four large information technology firms (Cisco, Hewlett Packard, IBM, and Intel) and seven universities (Carnegie Mellon University, Georgia Institute of Technology, Rensselaer Polytechnic Institute, Stanford University, UC Berkeley, the University of Illinois at Urbana-Champaign, and the University of Texas at Austin) agreed on a statement of principles for collaborative research on open-source software that emphasizes liberal dissemination of the results of collaborative work funded by industrial firms.[10] The GUIRR conference mentioned above is one of a series of meetings involving industrial firms, the Industrial Research Institute (representing R&D directors of large U.S. firms), and the National Conference of University Research Administrators.

Most of the tensions that have received considerable press and some attention from policy makers involve relationships between established firms and universities—indeed, in some respects, the economic interests of established firms with large patent portfolios may differ from those of small start-up firms that are owners or licensees of far fewer patents. Moreover, most of the major conflicts have involved firms outside the biomedical sector, reflecting the fact that the value of individual patents in industries such as information technology typically is lower than in biomedicine. Nevertheless, the current controversies and discussions among U.S. industrial firms and U.S. research universities may result in a rethinking by universities of the value of patents in efforts to sustain collaborative research relationships with U.S. industry.

Conclusion

The relationship between U.S. university research and innovation in industry is a long and close one. Indeed, organized industrial research and the U.S. research university both first appeared in the late 19th century and have developed a complex interactive relationship. The unusual structure of the U.S. higher education infrastructure, which blends financial autonomy, public funding from state and local sources with federal research support, and substantial scale, provided strong incentives for university faculty members and administrators to focus their efforts on research activities with local economic and social benefits. Rather

[10] The Open Collaboration Principles (http://www.kauffman.org/pdf/open_collaboration_principles_12_05.pdf) cover "just one type of formal collaboration that can be used when appropriate and will co-exist with other models, such as sponsored research, consortia, and other types of university/industry collaborations, where the results are intended to be proprietary or publicly disseminated." According to the principles, "The intellectual property created in the collaboration [between industry and academic researchers] must be made available for commercial and academic use by every member of the public free of charge for use in open-source software, software-related industry standards, software interoperability, and other publicly available programs as may be agreed to by the collaborating parties." These principles originated in an August 2005 University and Industry Innovation Summit in Washington, DC, organized by the Kauffman Foundation of Kansas City and IBM. For more information, see http://www.kauffman.org/items.cfm?itemID=662.

than being exclusively concerned with fundamental scientific principles, much U.S. university research throughout the late 19th and 20th centuries focused on problems of agriculture, public health, and industry.

U.S. universities have made important contributions to industrial innovation throughout the past century, not least by providing both advanced research and education. The strong links between education and research sustained a close relationship between the evolving scientific research agenda and the problems of industry or agriculture, while providing an effective channel (in the form of trained students) for the transfer of this knowledge to industry and other economic sectors. In addition, many university researchers in engineering and medical schools maintained close ties with the users of their research and their graduates in industry, medical practice, and agriculture. The important role of U.S. universities in industrial innovation, particularly after 1945, also relied on factors external to the university, including venture capitalists, equity-based financing of new firms, and high levels of labor mobility between academia and industry.

The Bayh-Dole Act of 1980 did not transform university-industry links and relationships in the United States; rather, it modified the longstanding structure of incentives and constraints that supported collaboration between university and industrial researchers. As the cases of MIT, Stanford University, and UC Berkeley suggest, universities with long histories of close research links to industry appear to have shifted their priorities in managing patenting and licensing activities to accommodate a broader range of goals beyond those of maximizing royalty income. Claims by some critics within U.S. industry that the Bayh-Dole Act has added frictions to university-industry collaboration now appear to be triggering a broader debate over the appropriate management of research collaborations. It seems likely that further modifications in institution-specific policies will appear in the near future, reflecting the evolutionary nature of the century-old links between U.S. research universities and industrial innovation.

References

AUTM (Association of University Technology Managers). 2003. *The AUTM Licensing Survey: FY 2002*. Norwalk, CT: AUTM.

Bar-Shalom, Avital, and Robert Cook-Deegan. 2002. "Patents and Innovation in Cancer Therapeutics: Lessons from Cell Pro." *Milbank Quarterly* 80 (4): 637–76.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh. 2002. "Links and Impacts: The Influence of Public Research on Industrial R&D." *Management Science* 48: 1–23.

Cohen, Wesley M., Richard Florida, and Richard Goe. 1994. "University-Industry Research Centers in the United States." Center for Economic Development, Carnegie-Mellon University, Pittsburgh, PA.

Cohen, Wesley M., Richard Florida, Lucia Randazzese, and John Walsh. 1998. "Industry and the Academy: Uneasy Partners in the Cause of Technological Advance." In *Challenges to the Research University*, ed. Roger Noll, 171–99. Washington, DC: Brookings Institution.

Geiger, Roger L. 1986. *To Advance Knowledge: The Growth of American Research Universities, 1900–1940*. New York: Oxford University Press.

———. 1993. *Research and Relevant Knowledge: American Research Universities since World War II*. New York: Oxford University Press.

GUIRR (Government University Industry Research Roundtable). 1991. *Industrial Perspectives on Innovation and Interactions with Universities*. Washington, DC: National Academy Press.

———. 2003. "Background Paper Articulating the Need for a New Approach to University-Industry Relations." http://www7.nationalacademies.org/guirr/Draft_Concept_Paper.pdf.

Hall, Bronwyn H., and Rosemarie Ziedonis. 2001. "The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1976–1995." *RAND Journal of Economics* 32: 101–28.

Henderson, Rebecca, Adam B. Jaffe, and Manuel Trajtenberg. 1998. "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965–88." *Review of Economics and Statistics* 80: 119–27.

Jensen, Richard, and Marie Thursby. 2001. "Proofs and Prototypes for Sale: The Licensing of University Inventions." *American Economic Review* 91: 240–58.

Katz, Michael L., and Janusz A. Ordover. 1990. "R&D Competition and Cooperation." *Brookings Papers on Economic Activity: Microeconomics* 137–92.

Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter. 1987. "Appropriating the Returns from Industrial Research and Development." *Brookings Papers on Economic Activity* 3: 783–820.

Mansfield, Edwin. 1991. "Academic Research and Industrial Innovations." *Research Policy* 20: 1–12.

McGarey, Barbara M., and Annette C. Levey. 1999. "Patents, Products, and Public Health: An Analysis of the Cell Pro March-In Petition." *Berkeley Technology Law Journal* 14: 1095–116.

Mowery, David C., Richard R. Nelson, Bhaven N. Sampat, and Arvids A. Ziedonis. 2004. *"Ivory Tower" and Industrial Innovation: University-Industry Technology Transfer before and after the Bayh-Dole Act*. Palo Alto: Stanford University Press.

Mowery, David C., and Bhaven N. Sampat. 2001. "Patenting and Licensing University Inventions: Lessons from the History of the Research Corporation." *Industrial and Corporate Change* 10: 317–55.

National Science Board. 2006. *Science and Engineering Indicators 2006*. Washington, DC: U.S. Government Printing Office.

NIH (National Institutes of Health). 1998. "Report of the Working Group on Research Tools." http://www.nih.gov/news/researchtools/.

Rai, Arti, and Rebecca Eisenberg. 2003. "Bayh-Dole Reform and the Progress of Biomedicine." *American Scientist* 91: 52–59.

Trow, Martin 1979. "Aspects of Diversity in American Higher Education." In *On the Making of Americans*, ed. Herbert Gans, 271–90. Philadelphia: University of Pennsylvania Press.

———. 1991. "American Higher Education: 'Exceptional' or Just Different." In *Is America Different? A New Look at American Exceptionalism*, ed. Byron E. Shafer, 138–86. New York: Oxford University Press.

PART III

UIL-Related Policies of Universities

CHAPTER 11

Building Research Universities for Knowledge Transfer

The Case of China

Weiping Wu

Research, mainly in industrial countries, indicates that research-oriented universities can assist firms directly through a variety of links and the provision of skills and indirectly by way of spillovers. These universities contribute to national development. In several notable instances, they have supplied the crucial underpinnings of dynamic industrial clusters within metropolitan regions. Since the early 1980s, strategies for enhancing research and innovation capabilities have come to occupy a more central position in China's development policy as the country moves to catch up with the West. An important change has been the promotion of university-based research and commercialization, particularly by elite institutions for which the central government provides more funding.

The primary purpose of this chapter is to examine the economic contribution made by two elite universities in China—Fudan University and Shanghai Jiao Tong University (SJTU)—and analyze the effectiveness of their interactions with industry and the local economy. Ranked among the top and oldest universities in China and the best in Shanghai, Fudan and SJTU have been gearing up to shift toward a stronger research orientation. With joint funding from the Ministry of Education (MOE) and the Shanghai municipal government, they belong to an elite group of universities selected as part of a national program to develop world-class universities. This chapter characterizes the scale, nature, and disciplinary span of research conducted by the two universities and the evolution of their research focus. It will analyze to what extent and under what conditions the universities have promoted the growth of collaborative local and international networks to encourage ties between business and research. It also will analyze key institutional changes within the universities and policy changes at local and national levels that have allowed more engagement by the universities with the local economy.

The role of universities in research and innovation is often shaped by the national innovation system, as shown in the varied experiences of the United States, continental Europe, and Japan. Both public and private universities in the United States have long played a significant role in conducting research that contributes to technological development and industrial performance (Mowery and Rosenberg 1993; Owen-Smith and others 2002). There are diverse interfaces between research universities and the industrial sector. University-industry relations in continental Europe (perhaps with the exception of Germany), by contrast, have encountered legal prohibitions against faculty collaboration with commercial firms in some countries and cultural biases against academic involvement with commerce in others. Since the late 1980s, however, attention has shifted to technology policy and academic technology transfer (Owen-Smith and others 2002; Poyago-Theotoky, Beath, and Siegel 2002). Although in Japan industrial firms tend to incorporate the process of innovation in-house, extended economic recession and concerns about reduced competitiveness in key industries promoted the recent expectation that the application of scientific research might lead to economic revitalization. Currently, there is a shift toward university research, especially longer-term research with potential commercial implications (Etzkowitz and others 2000; Kodama 2005).

Research also shows that, within the university, there are important institutional underpinnings for building commercial links. The primary source of growth in university licensing stems from an entrepreneurial bent by the university administration rather than a change in the focus of faculty research (Thursby and Thursby 2004). University administration can influence the incentives of the technology-transfer office and faculty members by establishing universitywide policies for sharing licensing income. Evidence from the United States indicates that a shift in the licensing behavior of universities is responsible for the surge in licensing activities (Poyago-Theotoky, Beath, and Siegel 2002; Thursby and Thursby 2004). The existence of a formal relationship with a science park enables a university to generate more patents and also allows it to more easily place doctoral students and hire eminent scholars (Link, Scott, and Siegel 2003). The majority of university inventions are embryonic; hence, successful commercialization depends critically on the faculty's participation in further development. Faculty involvement needs to go well beyond simply disclosing research, with faculty members often identifying licensees as well as working with licensees on further development (Jensen and Thursby 2001; Thursby and Thursby 2004).

National and Local Initiatives to Promote University-Based Innovation in China

Since 1979, China's national innovation system has been undergoing drastic reform. Many of the major national science and technology (S&T) programs launched since the mid-1980s have made significant imprints on universities. Most such programs are administered through the Ministry of Science and Technology (MOST). Although universities have yet to become key drivers of national research and development (R&D), they are now substantial players in two programs focused on basic research (see table 11.1)—"Climbing" (later "973") and "863" (Hu and Jefferson 2004). Universities carry out about one-third of the "863" projects and close to two-thirds of projects funded by the National Natural Science Foundation (*Science and Technology Industry of China* 2000). But universities have consistently spent less than other R&D institutions, growing from Y 2.8 billion to Y 6.4 billion between 1995 and 2000, a little over 10 percent of total R&D expenditures (Hsiung 2002). In Shanghai, university expenditures in S&T-related activities (a much broader category of spending than R&D expenditure) reached Y 2.76 billion in 2003, a mere 1.2 percent of the city total (Shanghai Science and Technology Commission 2004).[1]

To further promote university-based research, which had been seriously neglected in the period before the reform, the central government

[1] Private technology enterprises, by contrast, accounted for 86 percent of Shanghai's S&T-related expenditures in 2003.

Table 11.1. Major National Programs with an Impact on University Research in China

Program	*Agency*	*Start date*	*Key focus*
"863" National High Technology Research and Development Program	MOST	March 1986	To enhance international competitiveness and improve overall capability of R&D in high technology (with 19 priorities)
National Key Technologies R&D Program	MOST	1982	To apply R&D to meet critical technological needs in key sectors
"973" National Basic Research Program	MOST	June 1997 (combined with the "Climbing" program initiated in 1992)	To strengthen basic research in line with national strategic targets (primarily in agriculture, energy, information, resources and environment, population and health, and materials)
R&D Infrastructure and Facility Development	MOST	1984 (National Key Laboratories Program)	To implement the National Key Laboratories Development Program, National Key Science Projects Program, and National Engineering Technology Research Centers Development Program
National Natural Science Foundation	National Natural Science Foundation	February 1986	To promote and finance basic research and some applied research
"211"	MOE	1995	To improve overall institutional capacity and develop key disciplinary areas in select universities and to develop a public service system of higher education (3 networks)
"985"	MOE	1998 (first phase) 2004 (second phase)	To turn China's top universities into world-class research universities

Sources: Hsiung 2002; Hu and Jefferson 2004; Ma 2004; http://www.most.gov.cn/eng/programmes/programmes1.htm; http://program.most.gov.cn/; http://www.edu.cn/.

(primarily through the MOE) is providing more funding to elite universities (Hsiung 2002; Ma 2004; Suttmeier and Cao 1999). An important initiative was "Project 211," which provides significant funding for building on university campuses and for developing new academic programs around China (Hsiung 2002). Jointly sponsored by the State Planning

Commission, the Ministry of Finance, the MOE, and provincial governments, this project targeted a group of about 100 institutions during the ninth five-year plan period (1996–2000). Both Fudan and SJTU were recipients of 211 funding. On the heels of Project 211, the MOE launched another nationwide program, "985," aimed at turning China's top universities into world-class research universities. Competition for 985 designation was fierce because selected institutions received substantial funding to expand their research capacities and disciplinary scope, with matching funds from provincial governments. Again, Fudan and SJTU were successful in the competition for two phases of the 985 program.[2]

Broader university reforms also have been under way in curriculum development, faculty recruitment, and enrollment expansion. Various initiatives have been introduced to link schools run by different ministries in an effort to avoid repetition of specializations. Universities also are reforming their curricula to eliminate excess subjects and make the curriculum more flexible, interdisciplinary, and relevant. A series of aggressive programs has been designed to attract talented returnees to China from institutions overseas and to reward outstanding scientists; examples include the Hundred Talent Program and the Cheung Kong Scholars Program. In addition, nationwide university enrollment has expanded significantly.

Although these national programs have increased the funding and research capacity of select universities, their effect on university-industry links is indirect. A direct push for such links came in 2001, when the State Economic and Trade Commission and the MOE jointly set up the first group of state technology transfer centers in six universities (including SJTU) to promote the commercialization of technological achievements.[3] Perhaps even more important was a clear directive from the MOE in 2002 that encouraged the development of university enterprises, after some heated debate on whether commercialization and links with industry are a central mission of universities. These debates were highlighted by six circulars endorsed by then–vice premier Li Lanqing. After the selection of

[2] The "985" program's first phase, which began in 1999, funded only nine universities: Beijing University, the Chinese Science and Technology University, Fudan, Harbin Industrial University, Nanjing University, Qinghua University, STJU, Xi'an Jiaotong University, and Zhejiang University. In 2004, the second phase included 34 universities (Ma 2004).

[3] The six universities are Central China University of Science and Technology, East China University of Science and Technology, Qinghua University, Sichuan University, SJTU, and Xi'an Jiaotong University (http://www.edu.cn/20011122/3011306.shtml).

a new minister of education, Zhou Ji, who oversaw a number of university enterprises as a professor in Wuhan, the debates came to closure, with a clear official position (personal interview with a Fudan University official, June 14, 2005). This position states that the three major missions of universities are teaching, research, and commercialization. Research and technological innovations are seen, at least from the MOE's point of view, as a key mechanism by which universities contribute to national and local economies (*Chinese University Technology Transfer* 2002).[4]

Under China's recent reforms, university-industry links are built through two broad categories of mechanisms (Zhang 2003). The first is technology transfer through licensing and other arrangements, such as consulting, joint or contract R&D, and technology services. This mechanism resembles how universities in the West build industry links. The second mechanism, which is almost uniquely Chinese, is university enterprises (broadly defined) that are invested in and wholly owned by universities, operated and owned jointly with other entities, or partially invested in by universities (Ma 2004; Zhang 2003).

The tradition of university enterprises actually dates back to the late 1950s, when they served as sites for students' experiential learning, as generators of employment, and as a source of supplemental funding for universities. Only after the mid-1980s did the commercialization of faculty research become a key function of university enterprises, although even today the majority of them are not technology enterprises. In addition to commercialization, enterprises are viewed as a way to provide supplemental funding for university operation and to absorb surplus personnel on campus—because public universities are not allowed to lay personnel off (Zhang 2003). The local effect of university-based innovation and entrepreneurship, however, is still limited. In 2001, only about 40 percent of university enterprises were involved in S&T-related activities (Ma 2004). Their sales revenue made up a mere 2.3 percent of the revenue of all high-tech enterprises nationwide; nearly half of such revenue was contributed by enterprises affiliated with Beijing and Tsinghua universities. The national estimate is that only about 10 percent of university research and innovation has been commercialized (*Science and Technology Industry of China* 2000).

[4] As early as 1993, such a position was being promoted by the MOE and the MOST (Yang and Xu 2004), but they had run into resistance from some university administrators.

Building World-Class Universities and Industrial Links at Fudan and SJTU

One of the first steps for Fudan University and SJTU has been to assemble a comprehensive range of academic programs. In addition to their traditional strengths in science (Fudan) and engineering (SJTU), the universities have acquired new programs by expanding their curricula and merging with other institutions (particularly medical schools). Fudan has made a small inroad into engineering and has created a medical center with significant research strength and clinical capacity by merging with the Shanghai Medical University. SJTU has developed select programs in science (primarily of an applied nature) and built humanities, law, and business schools. It also established a medical school in the hope of merging with a local medical university and eventually took in Shanghai No. 2 Medical University in the summer of 2005.

A rapid rise in student enrollment, particularly of students pursuing master's and doctoral degrees, has accompanied the academic expansion. Both universities are looking into new ways to enhance student learning and research, with Fudan leading the way by allowing students to choose and change majors more freely. They also have worked to cater their teaching and training programs to the needs of the local labor force through continuing education programs, professional certificates, and correspondence programs.

The research capacities of Fudan and SJTU have increased as a result of academic expansion as well as open recruitment of top-notch faculty members nationwide (and even worldwide) through competitive mechanisms. Open recruitment is a welcome development and will likely increase academic quality and diversity, because most elite Chinese universities have a deep-seated tradition of hiring their own graduates. There is steady growth in publications in internationally recognized journals and proceedings in science and engineering. With its strength in sciences, Fudan scores higher in the Science Citation Index Expanded (SCIE), and its recent diversification into engineering also shows promising results in the Engineering Index (EI). SJTU fares significantly better in the EI because of its distinction in engineering, and it is catching up rapidly in the SCIE. By all accounts, SJTU appears to lead in research publications and domestic patents since 2000, although it has a slightly larger faculty. Its standing at the national level also has improved more markedly. In 2001, it ranked seventh in the SCIE, second in the EI, third in the ISTP (Index to Scientific and Technical Proceedings), and second in patents among all Chinese universities (SJTU 2003).

The improvement in research output also can be attributed to the stronger financial incentives that university administrations provide for faculty research and publication. More importantly, motivation for research comes in the way that the annual evaluation of the faculty is carried out. As under the commune system that started in the late 1950s in China, faculty members must meet an annual workload quota that may include courses offered, research published, and graduate students supervised. Those with a higher research output can easily substitute publications for teaching—a practice similar to that in the leading U.S. universities, where research is more valued.

As in many top universities in China, Fudan and SJTU use separate administrative units to manage traditional technology transfer (often the S&T division or its affiliate) and university enterprises (a university enterprise office or group). Affiliated and working closely with the university's S&T division, SJTU's technology-transfer center (one of six in the country) effectively fulfills the first function. The center uses proactive approaches to identify marketable innovations patented by faculty members, to cultivate collaborative relationships with firms (such as Volkswagen, General Motors, and Baoshan Steel), and to seek research funding from local government sources. In fact, funds from local governments have become an increasingly important source of research expenditure for SJTU (from just over 5 percent in 1996 to more than 20 percent since 2000), while the share of funding from outside firms has declined from 63 to 33 percent (SJTU various years). Unlike its counterpart at Tsinghua University, the center at SJTU is not involved in university enterprises. Its footprint extends beyond Shanghai to the Yangtze River and Pearl River deltas, through branch offices and information exchange centers.

Licensing has yet to become a major mechanism for technology transfer. According to an SJTU center manager, only about 10 percent of all patents registered by the university are marketable (personal interview of an SJTU official, June 14, 2005). There are at least two explanations for this outcome. It is rare that faculty members get to continue to work on an early-stage technology after the basic concept has been licensed. If doing so becomes feasible, some faculty members prefer to maximize their income by working with firms directly instead of licensing the technology. However, most domestic firms do not plan new product lines or new technology. When the commercial potential of research innovations is uncertain, these firms are unwilling or unable to take them over for further development. Joint R&D collaboration appears to be a major mechanism for the two universities to connect with overseas firms and institutions. A significant component of joint R&D is the redevelopment of foreign technology to cater to Chinese firms and markets. Both university administrations also have set up science parks as a vehicle for building high-tech clusters. Some large, successful university enterprises are housed in the parks as well.

Using faculty research and innovation as knowledge capital to enter into enterprise operations is a far more significant mechanism for building commercial links than traditional technology transfer through licensing, particularly for Fudan. Fudan's president has decided that the university will not make direct financial investments from its budget into any enterprises, except for a small one-year incubator grant program for start-ups founded by Fudan's own graduates and select faculty members. University administrators are not directly involved in enterprise management and decision making. Fudan has even gone a step further in reforming the management and ownership structure of older university enterprises since 2000. In a matter of two years, all business entities formerly owned by Fudan and its subordinate schools and departments were closed, merged, or transformed into freestanding enterprises and moved off the campus.

The Commercialization and University Enterprise Management Office at Fudan promotes research spinoffs, manages assets operation and spinoff enterprises, and provides necessary business services. The office is the legal representative for the university in all spinoff enterprises and oversees the planning of Fudan's science park. Outside firms also participate in holding companies with Fudan (Walcott 2003). The office now is involved in more than 100 enterprises, which together contribute Y 70 million to Y 80 million to the university annually and employ about 800 people, or about one-fifth of university staff members. In addition, the office oversees an incubator, which primarily supports small enterprises created by Fudan graduates for one year, using funding from the city (Y 12 million a year), district (Y 5 million), and university (Y 5 million) (personal interview with a Fudan University official, June 14, 2005). The office then acts as a venture capitalist to finance the surviving small enterprises for two to three years through its investment company. When these enterprises become mature businesses, some are sold to larger firms and some even go public.

SJTU uses a somewhat different approach to university enterprises. It has directly invested university funds in technology spinoffs and has become the sole owner of some enterprises. All SJTU-affiliated commercial entities are under the oversight of the university enterprise group, which is chaired by the party secretary of the university; the president of the university serves as vice chair. As a result, university administration and enterprise decision making are often intertwined, which tends to result in less flexible management practices as well as ambiguous ownership structures. From time to time, the university has had to bail out unsuccessful firms, actions that are therefore viewed as being at odds with the traditional academic culture. Compounded by the proximity of enterprises to the campus, these commercial activities have generated some concerns, especially because some of the firms are engaged not in R&D but rather in profit-motivated activities.

Faculty members in both universities do not yet fully support university enterprises. Many feel that commercial interests may interfere with long-term research agendas, particularly the emphasis on basic research. Faculty involvement in enterprises also diverts resources from classroom teaching, even though according to the rules faculty members are required to devote 80 percent of their time to university responsibilities (personal interview with a Fudan University research center director, July 4, 2005). More important, faculty promotion guidelines continue to give much less credit to commercialization than to scholarly publications. On campus and off, the debate continues over whether higher education should keep a distance from the market. Yet the pull of financial gains is rather strong, given that the general faculty salary level remains moderate despite several efforts by the central government to raise it. The stronger likelihood of outside engagement for the more applied disciplines also has led to a situation in which faculty incomes can vary significantly across programs.

Conclusion

The experience of select Chinese universities shows that the vitality of research universities and spinoff enterprises is shaped by a national innovation system, as well as by the local policy and innovation environment. In particular, the critical policies determining the national R&D framework, the investment priorities for institutions of higher education, and the decision to reward commercialization are largely decided by the central government. The selection of Fudan and SJTU for both the 211 and the 985 programs has been crucial to their academic and resource expansion. The universities are gaining greater autonomy in several spheres, such as academic programs and curricula, administration, and fiscal matters, but they are still far from autonomous. When both are obliged to promote university enterprises under central directives, they can and have used very different investment and management approaches. What appears to be a setback may be the degree to which they are now jointly managed by the locality. With municipal matching funds and incentives come restrictive conditions that include, for instance, enrollment quotas for local students. The municipal government also requires the universities to quantify their contribution to the local economy and has probably overemphasized the commercialization of research.

The success of university technology transfer relies on the quality of the local innovation environment to a large extent. Fudan and SJTU have been keen on licensing patented research, but officials remain frustrated by the lack of intermediaries and the limited capacity of local firms to conduct further development. Compared with universities in the West, both Fudan and SJTU are significantly behind in using tacit forms of technology transfer, which tend to interfere with faculty research and teaching load. Whether there should be limits to university engagement in business activities remains an open question, given the potential conflict between industry's desire for quick results and the fundamental mission of universities to conduct long-term basic research. Fudan's approach to university enterprises appears to reduce this type of conflict, because the university administration is minimally involved in business activities and enterprises are given freer rein in making decisions.

Perhaps a more salient feature of the Chinese experience is the increasing entrepreneurial bent of its elite universities. Unlike their counterparts in the United States, Europe, and Japan, university administration and select faculty members in China appear to be more open to direct engagement in local economies, thereby strengthening the relationship between knowledge and practice. New and perhaps innovative institutions are coming of age as a result. Both SJTU's technology-transfer center and Fudan's university enterprise office perform functions far beyond those of traditional university technology-transfer offices in the West. Given the lack of local intermediaries and venture capital, they weave these functions into their own operations and become powerful gatekeepers to ensure the success of university-industrial links.

References

Chinese University Technology Transfer. 2002. October issue, 10.

Etzkowitz, Henry, Andrew Webster, Christiane Gebhardt, and Branca Regina Cantisano Terra. 2000. "The Future of the University and the University of the Future: Evolution of Ivory Tower to Entrepreneurial Paradigm." *Research Policy* 29 (2): 313–30.

Hsiung, Deh-I. 2002. "An Evaluation of China's Science and Technology System and Its Impact on the Research Community." Special report for the Environment, Science and Technology Section, U.S. Embassy, Beijing, China.

Hu, Albert G. Z., and Gary H. Jefferson. 2004. "Science and Technology in China." Paper presented at Conference 2—China's Economic Transition: Origins, Mechanisms, and Consequences, Pittsburgh, PA, November 5–7.

Jensen, Richard, and Marie Thursby. 2001. "Proofs and Prototypes for Sale: The Licensing of University Inventions." *American Economic Review* 91 (1): 240–59.

Kodama, Toshihiro. 2005. "An Intermediary and Absorptive Capacity to Facilitate University-Industry Linkage: Based on an Empirical Analysis for TAMA in Japan." Paper presented at a workshop on Universities as Drivers of Urban Economies in Asia, sponsored by the Development Economics Research Group of the World Bank and the Social Science Research Council, Washington, DC, November 17–18.

Link, Albert N., John T. Scott, and Donald S. Siegel. 2003. "The Economics of Intellectual Property at Universities: An Overview of the Special Issue." *International Journal of Industrial Organization* 21 (9): 1217–25.

Ma, Wanghua. 2004. *From Berkeley to Beida and Tsinghua: The Development and Governance of Public Research Universities in the U.S. and China*. Beijing: Educational Science Press.

Mowery, David C., and Nathan Rosenberg. 1993. "The U.S. National Innovation System." In *National Innovation Systems: A Comparative Analysis*, ed. Richard R. Nelson, 29–75. Oxford, U.K., and New York: Oxford University Press.

Owen-Smith, Jason, Massimo Riccaboni, Fabio Pammolli, and Walter W. Powell. 2002. "A Comparison of U.S. and European University-Industry Relations in the Life Sciences." *Management Science* 48 (1): 24–43.

Poyago-Theotoky, Joanna, John Beath, and Donald S. Siegel. 2002. "Universities and Fundamental Research: Reflections on the Growth of University-Industry Partnerships." *Oxford Review of Economic Policy* 18 (1): 10–21.

Science and Technology Industry of China. 2000. March issue, 52.

Shanghai Science and Technology Commission. 2004. *Shanghai Statistical Yearbook on Science and Technology*. Shanghai, China: Shanghai Science Press.

SJTU (Shanghai Jiao Tong University). Various years. *Shanghai Jiao Tong University Yearbook*. Shanghai, China: SJTU.

Suttmeier, Richard P., and Cong Cao. 1999. "China Faces the New Industrial Revolution: Achievement and Uncertainty in the Search for Research and Innovation Strategies." *Asian Perspective* 23 (3): 153–200.

Thursby, Jerry G., and Marie C. Thursby. 2004. "Are Faculty Critical? Their Role in University-Industry Licensing." *Contemporary Economic Policy* 22 (2): 162–78.

Walcott, Susan. 2003. *Chinese Science and Technology Industrial Parks*. Burlington, VT: Ashgate.

Yang, Jirui, and Xiaomin Xu. 2004. *The Theory and Practice of University Enterprise Security*. Beijing: China Economics Press.

Zhang, Jue. 2003. The Development of High-Tech Enterprises in China's Universities. Wuhan, China: Huazhong Science and Technology University Press.

CHAPTER 12

Approaches to University-Industry Links

The Case of the National University of Singapore

Poh-Kam Wong

In common with other newly industrialized economies (NIEs) in Asia, Singapore is moving toward a knowledge-based strategy for economic growth (Wong, Ho, and Singh 2005). Policy makers have charted a course for Singapore's transition from an investment-driven economy to an innovation-driven economy, emphasizing the building of intellectual capital and its commercialization to create value and jobs. Although the role of Singapore's universities in nurturing talent has always been recognized, in the current period of economic transformation increasing prominence has been given to their role in stimulating economic growth through industrially relevant research, technology commercialization, high-tech spinoffs, attraction of foreign talents, and injection of an entrepreneurial mindset among graduates.

This paper draws substantially from Wong, Ho, and Singh (2006).

This brief chapter examines how the National University of Singapore (NUS), the country's leading university, seeks to change its role in the Singapore economy as a case study of how universities in East Asia are responding to the globalization of the knowledge economy. Singapore's case is of special interest because of the country's unique status as a relatively small city-state, where the pressure for globalization and the pace of the shift toward a knowledge-based economy are particularly intense. Hence, the challenges that the university system faces are likely to be symptomatic of those with which other small NIEs are likely to have to cope in the near future.

Overview of Singapore's Transition toward a Knowledge Economy

As highlighted by Wong (2002, 2006), Singapore has achieved one of the highest economic growth performances among NIEs, with average growth in gross domestic product (GDP) of more than 8 percent per year in the four decades between 1960 and 2000. Although the manufacturing sector has been a key engine for Singapore's economic growth, consistently accounting for more than one-fourth of total GDP, Singapore's rapid growth has also been sustained by the development of the city-state economy into a major regional and international hub in East Asia for trade, finance, transportation, communications, and an increasing range of knowledge-intensive business services (Wong and He 2005).

Table 12.1 summarizes the four distinct stages of postindependence economic development in Singapore and the accompanying changes in the focus of Singapore's national innovation system (Wong and Singh forthcoming). A distinctly new phase of economic development appears to be emerging in the new millennium, as the strategic focus for economic growth increasingly shifts toward a knowledge-based economy that incorporates three major sectors: (a) high-tech manufacturing, comprising a balanced high-tech enterprise ecosystem of large multinational corporations as well as young dynamic entrepreneurial start-ups and growth companies similar in spirit and style to the Silicon Valley model (Wong 2006) and incorporating the emerging life science sector (Wong, Ho, and Singh 2005); (b) knowledge-intensive business services that support Singapore's role as a value-adding regional business hub (Wong and He 2005); and (c) creative content production and distribution, which generate new sources of growth from the new media industries as well

Table 12.1. Stylized Stages of Singapore's Economic Development and National Innovation System Changes

	Stage of development			
	1960s–1970s	*1970s–1980s*	*1980s–late 1990s*	*From late 1990s*
Economic development	Beginning of direct foreign investment-driven, export-led industrialization	Transition to NIE	Transition from NIE to developed economy	Transition to knowledge-based economy
National innovation system	Primary focus on developing operative capability in manufacturing production	Primary focus on developing adaptive capability to support technological deepening	Primary focus on developing innovative capability to support applied R&D	Primary focus on developing intellectual capital creation and commercialization and entrepreneurial capability to support knowledge-based economic growth

Source: Wong, Ho, and Singh 2006.

as add to the cultural vibrancy of Singapore as a living environment for creative talent (Wong, Ho, and Singh 2005).

The primary focus of Singapore's national innovation system in this development phase is on the creation and commercialization of knowledge protected by intellectual property (patented high-tech innovations and trademarked designs, proprietary specialized knowledge assets and processes, and copyrighted creative content). Key parts of this shift are the development of entrepreneurial mindsets and the successful commercialization of knowledge. In particular, this phase calls for a fundamental reexamination of the traditional human resources development role of the university system in Singapore.

Overview of the National University of Singapore

Established in 1905, NUS is the oldest and largest public university in Singapore, with total student enrollment of about 28,000 and total faculty strength of about 1,800 in 2005. In recent years, NUS graduates made up about one-fourth of all tertiary graduates of the country. Following the British Commonwealth model, NUS was established with the primary mission of teaching and gradually took on an increasing role in research. As the only comprehensive research university in Singapore, NUS has held the status of a doctoral/research university—extensive under the Carnegie Classification of Institutes of Higher Learning since the late 1980s. By the early 2000s, it emerged as a leading university in Asia in terms of academic reputation. In 2000, it was ranked fifth in *Asiaweek*'s list of Asia's best universities. More recently, it placed among the top 25 universities in the 2004 and 2005 *Times Higher Education Supplement*'s ranking of the top 200 universities in the world, and it was the fourth highest ranked in Asia.[1] With an annual research and development (R&D) budget of about S$165 million, NUS alone accounts for about 5 percent of all R&D spending in Singapore.

Policy Shift of NUS toward an Entrepreneurial University

In line with emerging trends among universities (Etzkowitz, Webster, and Gebhardt 2000), NUS began, in the late 1990s, to articulate a vision of becoming more of an entrepreneurial university, moving beyond its traditional missions of education and research to take on the commercialization of technology in the context of economic development. This shift was given particular impetus in 2000 with the appointment of a new university president, Professor Choon-Fong Shih, a Singaporean who obtained his doctorate in material science from Harvard University and subsequently acquired substantial industrial R&D experience at General Electric as well as university research administration experience as director of a major research institute at Brown University. Emphasizing the need to make the university more entrepreneurial, he authored a new vision statement for NUS—"Toward a Global Knowledge Enterprise"—to drive home the new strategic focus of the university.

An integral part of his strategy is the establishment of a new division within the university called NUS Enterprise. NUS Enterprise is intended to inject a more entrepreneurial dimension in the university's education and research and to generate more economic value from the university's intellectual resources. Under NUS Enterprise, the technology licensing office has been reorganized to become more inventor friendly, with an overall focus on getting a larger proportion of NUS inventions into the marketplace, whether through licensing to existing firms or through spinning off new firms. The industrial liaison function is also being expanded

[1] The complete listing can be found at http://www.thes.co.uk/statistics/international_comparisons/2004/main.aspx.

to increase university-industry research collaboration and to attract a greater amount of industry-sponsored research funding. The new Venture Support unit has been established to provide a range of support services to NUS professors and students wishing to commercialize their inventions or expertise. Services include the provision of incubator facilities on campus and in California's Silicon Valley and the establishment of a seed fund that provides funding at a very early stage to NUS spinoff companies. A separate student start-up fund was also established to provide smaller seed funding to new ventures initiated by students. Both the seed funds receive matching funds from the Singapore government.

Another key aspect of the new strategy is to inject an entrepreneurial element into the educational program, so as to equip NUS graduates with the technical knowledge and scientific thinking skills needed to function in the knowledge-based economy, as well as to instill in them an entrepreneurial and innovative mindset and expose them to basic business know-how. To achieve this, NUS tasked the new Entrepreneurship Centre within NUS Enterprise with the mission of significantly expanding the teaching of entrepreneurship courses to all students on campus, particularly students in engineering, computing, and science. A so-called technopreneurship minor can be taken by any undergraduate student, while graduate-level elective courses in new venture creation were targeted to graduate students interested in commercializing their inventions. The center was also given the task of raising awareness and interest in entrepreneurship among students and faculty. It performed this task through a wide range of outreach activities, such as organizing national and international business plan competitions each year, nurturing the development of an active student entrepreneurship society on campus, and conducting regular techno-venture forums that bring prominent entrepreneurs and venture professionals to campus to speak. The center also began building a network of entrepreneurs, venture capitalists, and angel investors to provide NUS spinoffs with mentoring by practitioners and access to external venture funding.

In addition to pushing for greater enterprise through the NUS Enterprise Division, the new university vice chancellor also seeks to globalize the university. He argues that, with growing global competition for faculty, students, and resources, NUS needs to adopt globally competitive governance and practices. In this globalization drive, he began to shift the emphasis away from developing local human resources to incorporate the objective of making the university a global educational hub, attracting top foreign students and faculty members in increasing competition with other leading universities in the world. NUS began revising its faculty compensation and policy, making it more flexible to allow the university to pay more to attract top talent, as well as to reduce pay for underperforming faculty members. Tenure and promotion policy was made much more stringent and performance based, in line with the benchmarks of leading universities in the United States. The intake of foreign students also increased, and a larger share of local students are encouraged to attend exchange programs abroad for at least a semester.

A new initiative called the NUS Overseas College (NOC) Program integrates globalism and entrepreneurship. Implemented under the umbrella of NUS Enterprise, the NOC Program selects some of NUS's brightest and most entrepreneurially minded undergraduate students and sends them to five high-tech entrepreneurial hubs around the world to work as interns in high-tech start-up companies for one year. During that year, they also take courses related to entrepreneurship at partner universities in each region. In essence, the NOC Program represents an experiment in learning entrepreneurship by immersing the student as an apprentice in a high-tech start-up or growth enterprise in a foreign location, to expose them to the tacit aspects of entrepreneurial practice and foreign business culture. The program does not expect the students to be able to start their own ventures right after graduation; rather it aims to instill in them an entrepreneurial mindset that will orient their research toward commercializable innovation, as well as influence their future career choices toward more entrepreneurial and innovative settings. In addition, the program aims to help them establish valuable lifelong social networks with the entrepreneurial communities in high-tech hotspots overseas, so that they will be more inclined and better equipped to work in or found high-tech start-ups with global aspirations. The NOC Program launched the first entrepreneurial hub in Silicon Valley in 2002, followed by hubs in Philadelphia in 2003, in Shanghai in 2004, in Stockholm in 2005, and in Bangalore in 2006. Academic collaborations were developed with selected partner universities in the overseas locations, such as Stanford University in Silicon Valley, Fudan University in Shanghai, and the Royal Institute of Technology (Kungliga Tekniska Högskolan, or KTH) in Stockholm.

Effect of NUS's Shift toward the Entrepreneurial University Model

Although the policy shift toward the entrepreneurial university model is still in its early stage, some visible changes can already be detected, as summarized in table 12.2. In essence, although there was only a moderate expansion of the university in terms of the conventional performance dimensions of education output and research output, a more dramatic change can be observed in the new dimensions of foreign talent attraction, entrepreneurship promotion, and technology commercialization. These findings are further elaborated below.

Patenting

The number of patent applications from and patents granted to NUS has visibly increased in the 2000s compared with the 1990s. The total number of NUS patent applications grew from an annual average of fewer than 80 between 1997 and 1999 to more than 100 in 2004. The number of patents granted also registered a distinct increase between 2000 and 2004, averaging 30 per year versus 13 per year between 1997 and 1999.

Table 12.2. Profile of Changes in NUS before and after Shift to Entrepreneurial University Model

Indicator	*FY 1996/97*	*FY 2004/05*
Teaching staff	1,414	1,765
Foreign share (%)	39.0	51.9
Research staff	843	1,087
Foreign share (%)	70.1	78.6
Undergraduate students enrolled	17,960	21,761
Graduate students enrolled	4,478	6,461
Graduate students share of total enrollment (%)	20.0	22.9
Foreign students studying at NUS (%)	13[a]	27.6
Total research funding[b] (S$ million)	—	165.2
Share of industry-sponsored research[c] (%)	—	12
Total research projects funded[b]	1,751	1,841[b]
Research publications	4,949[d]	6,470[e]
Share of articles in refereed journals (%)	34.7	42
Patents filed	13	124
Patents granted	4	51
Cumulative patents granted by USPTO and IPOS	30[f]	311[g]

Sources: NUS various years; U.S. Patent and Trademark Office; Intellectual Property Organization of Singapore.

Note: — = not available.

a. Percentage of total student intake for 1997–98.

b. Figure for fiscal year 2003/04.

c. Includes foundations and individuals.

d. Calendar year 1997.

e. Calendar year 2002.

f. Calendar years 1990–97.

g. Calendar years 1990–2004.

With 162 patents granted by the U.S. Patent and Trademark Office (USPTO), NUS by 2004 became the third largest holder of U.S.-granted patents on Singapore-based inventions. NUS's share of total U.S. patents granted to Singapore-based inventors has increased over time, from 3.0 percent between 1990 and 1994, to 4.6 percent between 1995 and 1999, to 5.1 percent between 2000 and 2004.

Licensing

A clear increase in the intensity of technology commercialization from 2000 is also evident. As of the end of fiscal year 2004, NUS had made 239 technology licensing agreements. Of these, only one-fourth were issued before 2000; the remaining three-fourths were signed between 2000 and 2004. The majority of NUS licenses up to 2003 were signed with commercial companies (44.8 percent) or NUS start-ups (29.5 percent); the remainder were signed with government bodies or public research institutions.

Entrepreneurial Spinoffs

The results of NUS's change in policy after 2000 are also evident. Of the 82 spinoffs and start-ups formed between 1980 and 2004, two-thirds were established from 2000 onward. Focusing only on spinoffs, which are companies formed to commercialize NUS's patented inventions (as opposed to other faculty start-ups that do not involve NUS-owned intellectual property), one finds that NUS's average spinoff formation rate of four to five per year in recent years is creditable, even though it remains much lower than those of some of the top American universities, such as the Massachusetts Institute of Technology (23 spinoffs in 2002), Stanford (13), and Harvard (7) (Wong and Ho 2006).

Industry-Sponsored Research

The proportion of university R&D expenditure accounted for by industry-sponsored research has also visibly increased over the past few years, reaching 12 percent in fiscal year 2004/05. Although this proportion is still lower than proportions in the Massachusetts Institute of Technology and Imperial College, it is higher than the average among many leading U.S. and U.K. universities (Wong and Ho 2006).

Attraction of Foreign Talent

A marked increase in NUS's role in attracting foreign talent is also evident in terms of both student intake and recruitment of faculty members and researchers. Between fiscal years 1996/07 and 2004/05, the proportion of foreign students in NUS's student population doubled, from 13 percent to more than 27 percent, while the share of foreigners among faculty members increased from 39 percent to more than 50 percent. The share of foreigners among researchers increased from 70 percent to almost 80 percent.

Conclusion

In summary, this analysis indicates that NUS's role as a tertiary educational institution changed qualitatively in the period before and after 2000, shifting from the traditional focus on education and research to a more visible role in knowledge commercialization through increased patenting, licensing to private industry, and spinning off of new ventures. It is by no means certain that NUS's shift toward the entrepreneurial university model will eventually lead to significant economic payoffs. However, one can take heart from the fact that some of the leading U.S. universities, in terms of technology commercialization, also took a long time to achieve commercial viability in terms of their technology licensing office operations (Shane 2004).

Besides knowledge commercialization, findings of a high and increasing level of recruitment of foreign students, researchers, and faculty members by NUS also suggest that an entrepreneurial university model for universities in small, open economies needs to incorporate the additional role of attracting foreign talent. Although the level of involvement of foreigners in NUS is probably exceptional by the standards of East Asian universities—and perhaps even when compared with Anglo-Saxon universities—it does suggest that an ability to compete for talent on a global scale is likely to rank as an important feature of any entrepreneurial university model for NIEs.

Last, but not least, NUS's experiment in injecting a more entrepreneurial dimension into the educational experience of its students, particularly those in technical fields, may be instructive for many universities facing a similar challenge of making their technical graduates more business savvy and entrepreneurially minded. The conventional solution of concentrating on technical specialization and leaving the injection of business skills and entrepreneurial acumen to a later stage (for example, through an MBA program) may not be optimal for the increasingly dynamic labor market of a global, knowledge-based economy, in which creativity, entrepreneurial mindset, social skills, and international networking take on increasing importance.

References

Etzkowitz, Henry, Andrew Webster, and Christiane Gebhardt. 2000. "The Future of the University and the University of the Future: Evolution of Ivory Tower to Entrepreneurial Paradigm." *Research Policy* 29 (2): 313–30.

NUS (National University of Singapore). Various years. *Annual Research Report*. Singapore: NUS.

Shane, Scott. 2004. *Academic Entrepreneurship: University Spin-Offs and Wealth Creation*. Cheltenham, U.K.: Edward Elgar.

Wong, Poh-Kam. 2002. "From Using to Creating Technology: The Evolution of Singapore's National Innovation System and the Changing Role of Public Policy." In *Competitiveness, FDI and Technological Activity in East Asia*, ed. Sanjaya Lall and Shujiro Urata, 191–238. Cheltenham, U.K.: Edward Elgar.

———. 2006. "The Re-making of Singapore's High Tech Enterprise Ecosystem." In *Making IT: The Rise of Asia in High Tech*, ed. Henry Rowen, Marguerite Hancock, and William Miller. Stanford, CA: Stanford University Press.

Wong, Poh-Kam, and Zi-Lin He. 2005. "A Comparative Study of Innovation Behaviour in Singapore's KIBS and Manufacturing Firms." *Service Industries Journal* 25 (1): 21–42.

Wong, Poh-Kam, and Yuen-Ping Ho. 2006. "International Benchmarking of NUS." Working Paper, National University of Singapore Entrepreneurship Centre, Singapore.

Wong, Poh-Kam, Yuen-Ping Ho, and Annette Singh. 2005. "Singapore as an Innovative City in East Asia: An Explorative Study of the Perspectives of Innovative Industries." Policy Research Working Paper 3568, World Bank, Washington, DC.

———. 2006. "Towards an Entrepreneurial University Model to Support Knowledge-Based Economic Development: The Case of the National University of Singapore." Working Paper, National University of Singapore Entrepreneurship Centre, Singapore.

Wong, Poh-Kam and Annette Singh. Forthcoming. "The National System of Innovation in Singapore." In *Small Economy Innovation Systems: Comparing Globalisation, Change, and Policy in Europe and Asia*, ed. Charles Edquist and Leif Hommen. Cheltenham, U.K.: Edward Elgar.

CHAPTER 13

University-Industry Links and Enterprise Creation in India

Some Strategic and Policy Issues

Rakesh Basant and Pankaj Chandra

Studies of university-industry links (UILs) in U.S. and European clusters reveal that a variety of links exist between research and development (R&D) universities and firms near high-tech city clusters, although nonlocal links are often equally varied (see, for example, Adams 2001; Arundel and Geuna 2001; Athreye 2001; Best 2000; Lawson 1999; Saxenian 1994). In addition, the size, innovativeness, and strategies of local firms influence the nature and extent of UILs in a geographically bound cluster. The role that UILs can play has been a matter of discussion in India in recent years. This chapter puts together information on some interesting experiments undertaken by well-known educational institutions to enhance their links with industry and explores whether some key strategic and policy lessons can be gleaned.

A wide variety of UILs can exist (see Basant and Chandra 2006):

- Labor market–related links wherein educational institutions train laborers for industry's existing skill needs and also respond to emerging needs by establishing new programs and courses. New institutions focusing on these needs may also emerge.

- Links that respond to the demand for and the supply of goods and services (for example, testing, certification, and prototype development), especially in the region where the institution is located.
- Links arising through the creation of new enterprises, through spinoffs or incubation.
- Links for the creation, acquisition, and dissemination of knowledge through student projects, technology licensing, consulting, joint R&D projects, and so on.

Many of these links can be informal. Most academic institutions in developing countries do not have formal technology-transfer and consulting offices. Until very recently, even in industrial countries such as Japan, UILs were informal—in large measure to avoid the cumbersome official procedures for handling patentable inventions (Geiger 2001; see also Branscomb, Kodama, and Florida 1999). Moreover, while federal and state policies (including those related to trade, investment, and education) may affect the formation of all four types of links, city-specific initiatives as facilitators have received major attention in recent years.

Complementarities can exist among these links. For example, links for creating and disseminating knowledge may give rise to opportunities for creating new enterprises. Links for training workers might also lead to similar outcomes, and so on. This chapter focuses on UILs that result in enterprise creation. The main objective is to highlight differences in the processes of enterprise creation in select well-known educational institutions in India so as to draw a few strategic and policy lessons. The rest of the chapter is divided into five sections. The first section summarizes the key findings of a recent short survey of spinoff activity in a few educational institutions in two Indian cities. The next section compares the enterprise creation efforts of two R&D-intensive educational institutions that have different organizational structures. The third section compares the models of enterprise creation in four Indian institutes of technology. The fourth section summarizes the incubation model being used at the Indian Institute of Management in Ahmedabad. The final section highlights some strategic and policy issues.

Spinoffs from Educational Institutions in Two Indian Cities

Our starting point is a short survey of 14 educational institutions in Bangalore and Pune (see Basant and Chandra 2006). Two of the institutions reported spinning off a firm. But most of the institutions, while being aware of the possibility for spinoffs, were still looking for opportunities. In India, spinoffs from academic institutions are still a nascent phenomenon. The respondents were asked why faculty and students from their institutions are not able to set up enterprises. Three reasons stood out: lack of seed funding, inappropriateness of research for commercialization, and absence of institutional regulations to set up firms. These responses are consistent with some available evidence that the venture capital industry in India is still in its infancy and that start-up funding is not easily available (Morris and Basant 2005). Research-oriented institutions are trying to cope with the intellectual property and other issues (for example, owning equity in spinoffs) that are very important in setting up new enterprises. Most publicly funded institutions in India, including the Indian institutes of technology (IITs), the Indian Institute of Science (IISc), and the like, have traditionally not been allowed to hold equity in ventures. This restriction is being changed (and is discussed below) through the creation of separate entities within these organizations and through the establishing of incubators.

The ability of institutions to build knowledge-based links and create enterprises is a function of the knowledge-creating activities they undertake. Only 3 of the 14 institutions reported any research or commercialization output in the preceding five years. Interestingly, the two institutions that reported spinoff activity were also very active in developing new technologies and applying for patents (Basant and Chandra 2006). Thus, not all institutions appear to have an adequate knowledge base for participating in knowledge-based networking activity and enterprise creation. Moreover, only a few of these institutions have systems for undertaking formal knowledge transfer. None of the institutions surveyed had a separate technology-transfer office. Institutions that have significant research output had informally identified individuals who help in patent filing and licensing activities. They also have arrangements with law firms to help these individuals. In addition to the research-oriented institutions, a few others had some rules for commercializing technologies developed in the institution. They appear to be anticipating the need for such norms as more interaction with industry takes place. The rules are similar across institutions: the inventor gets a reward; licensing rights are held by the institution, the sponsor, or both; and the first right to commercialize lies with the sponsor. Only one institution explicitly mentioned that it plans to hold equity in the venture. Another mentioned that it would prefer nonexclusive licenses. Most respondents said that commercialization activity is likely to increase in the near future, and some are seeking outside help to facilitate this transition.

The survey highlighted two issues with respect to the potential for enterprise creation in educational institutions in India:

- Only a few institutions have high-end links for basic and applied research that can result in technology-based enterprise creation. Most institutions primarily undertake training, testing, and prototype development activities, along with student projects.
- Very few institutions are able to raise funding for research and for activities that they do with industry. Lack of funding hinders the creation of links.

Apart from funding, the absence of institutional and policy incentives for researchers and institutions to build links, the lack of research orientation among local firms, and the inappropriateness of research undertaken for industry contributed to the absence of links. The rest of the chapter focuses on institutions that have a decent amount of research funding and outputs and explores their enterprise creation efforts.

R&D, Patenting, and Enterprise Creation: Two Profiles

IISc in Bangalore and National Chemical Laboratory (NCL) in Pune are representative of very high-end, research-oriented, academic institutions. There are, of course, a few critical differences between the two institutions. Although IISc was the result of a private endeavor (Tata) that subsequently got state support, NCL is part of the Council for Scientific and Industrial Research (CSIR) system of publicly funded research labs set up by the federal government. The research profile of IISc is much more diverse than that of NCL, which essentially focuses on chemical and biotechnologies. In a sense, IISc is more like a research university with a wide variety of disciplines, whereas NCL is a top-ranking center for research in a specialized field with a vibrant doctoral program.

IISc was established in 1909.[1] In addition to formal education and research, the institute also offers industry the know-how it generates through both in-house research and industry-sponsored projects. More importantly, the institute has become known globally for its excellent quality of education and high research output in basic science and allied

[1] Most of the material in this paragraph is from the IISc Web site at http://www.iisc.ernet.in.

fields. Although it focuses on research, IISc was one of the first institutes in the country to build an extension wing for industry interactions. The Center for Scientific and Industrial Consultancy was established in 1975 to promote interaction and collaboration between the institute and the industry. The Society for Innovation Development was established in 1991 to extend this activity and help enterprises compete in the global market. IISc has been far ahead of NCL and other laboratories in terms of publication activity, but it lags behind them in patenting activity (*Business World* 2003).[2]

Basant and Chandra (2006) make clear that IISc's links with industry cover a large variety, in terms of technology and sectoral profile, of local (city-specific), national, and international entities. It has so far spun out seven companies, most in information technology and a few in biotechnology.

NCL was established in 1950 in Pune to carry out R&D in chemistry and related sciences.[3] It is widely considered one of the most distinguished public sector labs in India and currently has 364 research fellows and about 397 project staff members (of which more than 300 hold doctorates). NCL has many interdisciplinary research centers with interests in polymer science, organic chemistry, catalysis, materials chemistry, chemical engineering, biochemical sciences, and process development. It publishes approximately 350 papers per year in chemical sciences and files the largest number of patents from India. On average, NCL is granted about 50 Indian and 25 foreign patents per year. In fact, much of the recent improvement in the patenting record of public sector labs is attributable to NCL (*Business World* 2003; Mani 2002). NCL also produces the largest number of doctoral degrees in chemical sciences in India.

NCL has considerable interaction with industry through consulting and research projects. It raises a fair amount of research funding through those links (for some estimates, see Basant and Chandra 2006). As is the case at IISc, NCL has a diverse set of links with entities in the city and outside it, including links with foreign entities. But unlike IISc, NCL has not spun off a single enterprise. This fact is surprising, because NCL is far ahead of IISc in terms of patenting activity, a proxy (admittedly inadequate) of intellectual property creation. The conventional

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[2] IISc produced about 9,718 research publications from 1985 to 1996 (http://www.ncsi.iisc.ernet.in/iisc_publications.php). In addition, about 5,000 doctoral theses have been written at the IISc since its inception (http://www.iisc.ernet.in).

[3] Most of the material in this paragraph is from the NCL Web site at http://www.ncl-india.org.

wisdom is that intellectual property creation is critical for the creation of innovation-based enterprise. This wisdom does not appear to be relevant for IISc and NCL. Between the two R&D-intensive educational institutions, one would expect the institution oriented toward intellectual property to undertake more spinoff activity. Both institutions have flexible programs for faculty members who wish to set up enterprises. CSIR, the parent organization of NCL, has initiated a scheme wherein scientists can take leave for three years to set up or join start-ups. There have been no takers. IISc also provides a similar facility, which has been used. Several reasons for this apparent anomaly are possible:

- In general, scientists find enterprise creation too risky an endeavor, especially without any managerial support. NCL's public sector legacy may further inhibit enterprise creation.
- Some of those inhibitions can be reduced if institutional infrastructure provides support. It is likely that the market orientations of the technology licensing offices of the two institutions are different. Informal interactions indicate that although the Society for Innovation Development (at IISc) is oriented more toward spinoffs, the technology licensing office at NCL focuses more on intellectual property creation and licensing.
- At this stage of the evolution of India's premier academic institutions, patenting activity may not adequately reflect commercial orientation. The CSIR system, of which NCL is a part, has encouraged patenting for some years now, but incentives to create enterprises are relatively new and are not implemented seriously.

Given that appropriate infrastructure at the institution may be a critical factor in enterprise creation, we now move to the discussion of IITs, where such infrastructure has been created.

Enterprise Creation at IITs: Two Models

This section compares the models of enterprise creation adopted by four IITs. The comparison essentially is between the conventional incubation model adopted by the IITs in Kanpur, Delhi, and Bombay and an unconventional approach adopted by IIT Madras. We first briefly summarize the incubation-related initiatives at the three IITs and then contrast them with the initiatives at IIT Madras, which does not have a formal incubation center. The IIT Madras model has been able to achieve a much greater market orientation in its research activity, and its incubation efforts are much more flexible than those of the conventional model.

Incubation Efforts at IITs

The IITs in Bombay, Kanpur, and Delhi have set up formal incubation centers over the years. Although the broad strategy is similar at each one, there are a few differences.

IIT Bombay An information technology business incubator was set up at the Kanwal Rekhi School of Information and Technology at IIT Bombay in 1999.[4] The experiment had manifold effects on the IIT Bombay campus. Apart from successfully incubating a number of companies, the incubator also created an environment conducive to entrepreneurship. Encouraged by the success of the initial experiment, IIT Bombay set up a full-fledged technology business incubator to cover other areas of science and technology. This effort was supported by the Department of Science and Technology of the government of India. The Society for Innovation and Entrepreneurship (SINE) came into existence in 2004 to manage the business incubator and accelerate the growth of entrepreneurship in IIT Bombay. This institutional innovation was essential, because the IITs are not permitted to own equity. Some other IITs have created similar institutions to take care of such issues. On behalf of IIT Bombay, SINE holds equity in the incubatee companies, enters into revenue-sharing arrangements, and licenses technologies developed at IIT Bombay. As of June 2005, 19 companies had been incubated, of which 9 have graduated from the incubation program.[5] The incubator in Bombay is open only to IIT faculty members and students, and as of now, students and faculty members of the management school (as opposed to engineering and technology departments) are not actively involved in the incubation activity.

IIT Kanpur In collaboration with the Small Industries Development Bank of India (SIDBI), IIT Kanpur has set up the SIDBI Innovation and Incubation Centre (SIIC) to foster innovation, research, and entrepreneurial activities in technology-based areas.[6] The equivalent of SINE at IIT Kanpur, SIIC provides a platform for start-ups by prospective entre-

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[4] This summary is based on material available at http://www.sineiitb.org/.

[5] Further details about individual incubatees are available at http://www.sineiitb.org/incubatees.html.

[6] This description is based on material available at http://www.iitk.ac.in/siic/about1.html.

preneurs and intrapreneurs to convert their innovative ideas into commercially viable products. The research products of faculty members and students are upgraded and customized according to the requirements of the user of or the market for commercialization. Unlike IIT Bombay students, students of the MBA program of IIT Kanpur, working with a management consultant, help incubatee companies strengthen their business plans after conducting market surveys, if required, and developing financial plans. SIIC helps them find business partners and venture capitalists and provides consulting on business promotion with the help of the MBA students and faculty of IIT Kanpur and consultants. It supports three types of ventures:

- Nursery incubation projects initiated by members of the academic staff, students, or alumni of one of the IITs or other premier institutes, supported by the institute or some other technology promotion agency (government or nongovernment) with a view to trying out a novel technological idea for upgrading to a commercial proposition, scaling up a laboratory-proven concept, and setting up a technology business enterprise
- Technology-based start-up companies promoted by a first-generation entrepreneur desirous of R&D partnership with the institute or a company, with a view to trying out a novel technological idea that could be the basis for a commercial proposition, scaling up a laboratory-proven concept, and setting up a technology-based business enterprise
- A technology or R&D unit of an existing small or medium enterprise, industry association, or R&D company that desires to have a close technology interface with IIT Kanpur

Technically, people outside the institute can use the incubation support, but in practice, only staff members and students have used it. There are currently eight incubatees at IIT Kanpur (for details, see http://www.iitk.ac.in/siic/incubatee.html).

IIT Delhi An institutional arrangement similar to SINE operates at IIT Delhi, where the Foundation for Innovation and Technology Transfer (FITT) has been operating for quite some time.[7] In fact, FITT came into being before any other IIT incubator, as a part of the ICICI Bank– and World Bank–funded Technology Institution Programme. It was initially

[7] This description is based on material available at http://www.fitt-iitd.org/tbiu/.

set up as a technology licensing office and intellectual property rights cell. It now runs the Technology Business Incubation Unit, supported by government of India's Department of Science and Technology. As in Kanpur, the incubator can support three types of firms. Therefore, incubatees from outside the institute can also get support. But unlike in Kanpur, the business school at IIT Delhi is not involved in the incubation activities. The incubation center has admitted 12 companies, of which 6 have exited the program, but only 2 successfully.

Summary All three incubation activities discussed above are supported by an independent organization that has been set up by the IITs to manage the incubation process. These entities hold equity in the incubatee companies on behalf of the IITs, charge them for the services provided, and license intellectual property rights if necessary. All three IITs have business schools on campus, but only IIT Kanpur seeks to involve the business school in the incubation process to satisfy some of the managerial needs of start-ups. Even there, the interaction between the technology and the management parts of the institute is limited. The other two institutes have not yet tried such an interaction by design, but the possibility exists. There are some signs of such interaction picking up at IIT Bombay.

Spinoff Activity at IIT Madras: The Telecommunications and Computer Networking Group

The Telecommunications and Computer Networking (TeNeT) Group was formed by nine faculty members from the electrical engineering and computer science departments of IIT Madras with the objective of creating indigenous technological solutions for reducing network access costs in India.[8] The group, formed more than 12 years ago, consists of 14 faculty members. They work toward a few common goals in research and product development. The focus is to address the pressing needs of India and other developing countries by pursuing market-driven product development, strengthening the Indian telecommunications and networking industry, providing technical training and education, and driving telecommunications and information technology policy. The main objective is not enterprise creation; that is only the means to achieve the larger objective

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[8] This subsection is based on information available from http://www.tenet.res.in/, Basant and Chandra (2003), and interviews with Professor Ashok Jhunjhunwala and some other colleagues of the TeNeT Group.

of driving more equitable growth of the telecommunications industry in India by developing India-centric products. "World-class technology at an affordable price" is the vision of the group. In its endeavor to fulfill that vision, the group does not spend time and energy on the formal creation and protection of intellectual property. It believes that at the frontiers of knowledge in telecommunications technology, where technology and product life cycles are short, timing and cost-effective solutions are of the essence for survival and growth—not intellectual property.

The TeNeT Group has about 200 full-time researchers, engineers, other technical staff members, and project students working in more than 10 dedicated labs. Currently, the group works in diverse areas, including wireless communications; computer networking; fiber optics; digital systems architecture; network management systems; integrated voice, video, and data communications; Indic computing; and applications for rural development. The group explicitly recognizes the trade-off between academic publications and commercial R&D and has, at the margin, opted for R&D.[9]

Interestingly, the idea of floating a company came when the technology developed at IIT Madras could not be sold or licensed through conventional channels. The first company, Midas Communications Technologies, was set up with the help of nine former students. Through the creation of 15 new enterprises, the TeNeT Group has over the years developed and commercialized a large number of new technologies in telecommunications. All are for-profit companies set up with the help of former students. Professors Ashok Jhunjhunwala and Bhaskar Ramamurthy, two leading members of the TeNeT faculty team, have also established a section 25 (not-for-profit) company that holds equity in a firm called n-Logue.com, set up by the TeNeT Group to run telecommunications and Internet businesses on a franchise basis in rural areas and small towns of India using the access network developed by the group. Whether this company also holds equity in other companies set up by the TeNeT Group is unclear.

The model for different companies is similar; old students (and at times outside promoters) provide equity funding, and the TeNeT Group provides technical support. Initially, the companies and the TeNeT Group

[9] The expertise in the TeNeT Group spans the entire gamut of specializations pertinent to its mission: speech, audio, and video technologies; digital communications; wireless networks; computer protocols; optical communications; digital signal processing; computer vision; network management; multimedia; digital system design; and embedded systems. In addition, it has a small group of experts in areas such as rural finance and small-scale enterprises for rural areas.

raise research funding jointly. As the company grows, it starts to provide research funding to the TeNeT Group for specific projects. Consequently, over time the company becomes a source of research funds for the institute. The product or technology commercialized by the company is typically jointly owned by IIT Madras and the start-up. In the initial days, the firms operate out of IIT Madras laboratories.

The TeNeT Group has created and used a network of alliances for setting up and nurturing companies. The incubators at other IITs have not yet been able to build such a network. The ability of the TeNeT Group to do so partly emanates from the fact that the group focuses on a set of interrelated technologies in telecommunications in which the faculty members of the institute are internationally recognized. Examples of such links illustrate their variety and their strategic role:

- Early in the days of Midas Communications, the group realized the critical role of high-quality, specially designed integrated circuits (ICs) in the development of their product and also appreciated that such ICs (especially in small volumes) could not be developed in India. The group contacted Ray Stater, the chairman of Analog Devices, in the United States, who evaluated their technology and agreed to develop the ICs designed by IIT Madras. Analog Devices agreed to market the ICs outside India and give the group a royalty. It also agreed to help the group license the ICs within India. But most important, Analog Devices agreed to advance funds to the group against future royalty payments.
- The group needed large amounts of money in the beginning and hence decided to license the technology to other companies in India. Crompton Greaves, the Electronics Corporation of India, WS Telecom, and Shyam Telecom were initial licensees for IIT's satellite networking technologies. This funding helped support several research projects that got Midas off the ground.
- Very quickly the links with Analog Devices were strengthened through the formation of another company (Banyan Networks) with former IIT students and Ray Stater, who provided angel funding.
- To help professionalize the functioning of the start-ups, the group has been involving noted people in industry. For example, Arun Jain (chairman of Polaris Software, Chennai, a well-known information technology firm) is the chairman of one of the companies. Informally, Polaris has helped the TeNeT Group create an appropriate structure for the start-ups and hire the right people from industry. Interestingly,

Polaris subsequently became a copromoter in another start-up of the group and built applications and interfaces for the product of that company.
- Equity from external agents also helped professionalize the process of commercializing the technology. For example, Intel Corporation joined as the lead investor with IL&FS (Infrastructure Leasing and Financial Services), a company that receives funds from the state's (Tamil Nadu) Venture Fund. Intel also helped the company resolve several operational and other technical problems.
- The most interesting set of links have been formed among member companies of the group. They collaborate with each other in a variety of ways and are tied through input-output links. In some sense, these companies form the supply chain of certain technologies and services.[10]

The entire effort of the TeNeT Group revolves around the vision, leadership, and concerns of Professor Ashok Jhunjhunwala. He brought the technological base, links with well-trained students, a strong concern for societal change in developing countries, an ability to draw together a team of well-educated and trained people, international training and exposure, the reputation of being part of an excellent institution, and the credibility of an academician who is not partisan to the development of low-cost telephony in the country. But this vision and the world-class technological capabilities of the group (which help its members understand the implications of changing technological trajectories) would not have been useful without establishment of the right kind of links. With the formation of the start-ups and the maturity of their incubation model, the IIT team now focuses more on the R&D component of the activity, although earlier the team performed the entire R&D as well as the commercialization activities. Initially, IIT Madras and its allied companies filed several Indian patents, with the arrangement that the institute would hold patents for new technology while the companies would give royalties to the institute. Subsequently, the idea of patenting was given

[10] At one level, some of these companies represent different stages of the wireless-based technology chain for delivering low-cost telecommunication options in India and other developing countries. Midas has used Banyan's wired capabilities in its wireless products, and Banyan is using Midas' corDECT boxes in designing its wired solutions. Similarly, Nilgiri is developing network management systems for Midas and Banyan products in addition to other platforms. The company called n-Logue.com is simply a means to manage the franchise effort, using technologies developed by the other three companies.

up, because technology was changing so rapidly that time to market was considered to be more critical than intellectual property protection.

The core idea of agenda-based research to create enterprises around emerging needs can do quite well in a country such as India, where R&D costs are still low. This case is a good example of network-based enterprise development in which the core is technology R&D. It also reflects new vistas of academia-industry partnership and reflects rudiments of the organic evolution of a focused technology cluster. This center-satellite model, with a strong central R&D infrastructure and dynamic satellite application firms covering different stages of the technology supply chain, provides a viable model for technology development and implementation in India. The desire to build technology for developing countries without direct government funding, the ability to access quality engineering human resources, and the desire to compete with the best in the world provide a unique strength to this cluster. The group saw links as a source for acquiring complementary assets.

Summary

The formal incubation models of IITs at Kanpur, Bombay, and Delhi and the model at IIT Madras highlight the role of three factors for a successful enterprise creation model:

- Availability of a technology with commercial potential
- Appropriate mentoring and managerial inputs
- Networks that can facilitate the flow of knowledge and finance

Although the IIT Madras model gets to these through the agenda-based research and creation of strategic networks, the other IITs are trying a formal incubation model. Given the critical nature of these factors, the Indian Institute of Management, Ahmedabad (IIMA), is experimenting with an incubation model that explicitly accounts for them.

The Incubation Experiment at the Indian Institute of Management, Ahmedabad

The Centre for Innovation, Incubation, and Entrepreneurship (CIIE) was set up at IIMA to undertake research, training, and incubation in innovation-based entrepreneurship. The center manages the incubator at the IIMA called the Indian Incubator for Innovation-Based Enterprises. CIIE's main task is to integrate incubation with research and training, with the help of faculty, current students, alumni, and other partners and stakeholders. CIIE believes that management support is critical for the success of technology-based enterprises. CIIE conducts a nationwide competition for high-tech innovations with mass impact to identify innovations that can be converted into commercial enterprises. Winners are given incubation and other support. Several such projects are on the road to commercialization. Support provided by CIIE covers the entire chain from innovation to enterprise. These live incubation projects provide exciting learning opportunities for IIMA students, who conduct projects with incubatees, under the supervision of the IIMA faculty. As a part of the incubation process, CIIE works closely with design and product development centers, as well as with laboratories, to provide technology-related support to its incubatees. In fact, it works closely with three IITs and some other well-known technology institutions. Apart from providing managerial support to the incubatees at these technology and design institutions, CIIE also undertakes collaborative incubation with them.

Mentoring teams are formed for the selected innovators. Typically, these teams are headed by an IIMA faculty member and consist of experts in the technology domain of the innovation, entrepreneurs, and members of the venture capital industry. The mentoring teams identify the incubation needs of the incubatees. Needs that require managerial inputs are converted into student projects supervised by the IIMA faculty. Other incubation needs, including technology (for example, product development, process development, and testing), legal (for example, intellectual property protection) and design inputs, are provided through CIIE's network. IIMA is part of the National Entrepreneurship Network being created by the Wadhwani Foundation. As part of the incubation facility, the CIIE provides basic infrastructure and associated services. Infrastructure support includes office space, a library, a canteen, telecommunications, and back-office and computing facilities. In case the incubatee wishes to stay at some other location, long-distance incubation support is also provided. Commercialization support activities range from business plan development, market research, and consulting to legal, financial, and other forms of assistance. The graduation period of the incubatee is expected to be about 20 months.

Although incubators in technology institutions are primarily commercializing technologies developed in those institutions, CIIE provides support to technologies developed anywhere in the country. The focus is on high-tech and mass impact innovations. The incubation model is flexible enough to satisfy a variety of the incubatees' needs, including long-distance incubation. This experiment is new and cannot be evaluated yet. Six companies are being actively incubated, and one company is about to graduate. IIMA is now creating a separate institutional entity like the three IITs to manage the incubation center on behalf of the institute, hold equity, and so on. Students find the live projects very useful. There are also indications that some of the students who work on live projects with the start-ups will subsequently join them. Because a large part of the student population at IIMA comes from premier engineering and technology institutions, it is hoped that such a model will encourage more and more incubatees from premier technology institutions that do not have such facilities.

Concluding Observations

The activity of enterprise creation as a part of UILs is still at a nascent stage in India. The major role of UILs continues to be to satisfy the labor market needs of the industry and to provide research support through consulting and other research projects. But the focus on enterprise creation is generating a lot of excitement among the research-oriented science, technology, and management institutions. Conventional incubators are proliferating in India today. Virtually all well-known technology institutions have one, and some of the management institutions are also experimenting with incubation.

From the discussion in this chapter, a few interesting patterns emerge. As yet, intellectual property protection does not appear to be critical for spinoffs and new enterprise creation in Indian educational institutions. Most educational institutions keen to create start-ups have adopted the conventional incubation model. Enterprise creation through focused, agenda-based research appears to be an interesting alternative to the conventional model. However, it requires tremendous motivation on the part of the research group and the ability to deal with the trade-off between publication and enterprise creation. Some R&D institutions have just started to grapple with the patenting versus publication dilemma; therefore, the idea of enterprise creation might further sharpen this trade-off. At one level, it may make patenting more appealing, but given limited links between patenting and enterprise creation, the trade-off may become even more complicated. Indian culture discourages university faculty members from being entrepreneurs. Even the faculty reward system looks only at academic work. Can the system be changed? Can and should the creation of new ventures be made an important objective of academic institutions?

It is too early to assess the effect of enterprise creation efforts, begun only within the past five years, in educational institutions in India. No outstanding success has come to light, but many incubators can boast of moderate success. Although numbers are not available, many incubatee companies from technology institutions have survived the rigors of market competition after graduating from the incubators. At the moment, the most important contribution of such efforts has been to highlight the possibility of creating technological innovation-based enterprises in educational institutions. Their success, even if moderate, sharpens the focus on technology-based entrepreneurship as a career option. In addition, the recognition of these firms as innovative firms also has a positive externality in the sense of creating a focus on innovation among the entrepreneurs, especially young, technology-savvy ones. The potential social effect of some of the technologies commercialized by these enterprises (for example, the ones developed at IIT Madras) adds to the spillovers associated with enterprise creation activity in educational institutions.

At a broader level, the academia-industry links in India need to be analyzed in the context of a few larger processes. Until recently, the private sector in India was not very research oriented, partly because of the lack of competitive pressures and partly because the bulk of research was conducted in public institutions. Within public institutions, barring a few exceptions, research has moved out of Indian universities and other academic institutions over the years. For many years, the public sector research institutions have been the main centers of research activity and universities have largely remained as teaching institutions. This pattern is changing in two ways. First, the private sector has started to engage in research, and second, the academic institutions have started to face financial difficulties, which are partly being alleviated through sponsored research. The lack of industry orientation among academic institutions and the limited R&D orientation has constrained links between industry and academia over the years. As both change, more academia-industry links would be expected. Incubation and new enterprise creation activities may also pick up as these processes mature.

At the policy level, one critical problem is the absence of angel and venture funding for start-ups. Most of the so-called venture capital activity in India is actually growth funding and takes the form of private equity. It may be useful to think in terms of liberalizing the norms that deter insurance (and pension) funds from investing in venture capital firms. Such liberalization has just begun, but there is a long way to go.

Finally, research in industry and universities is complementary, and the success of academia-industry links lies in the exploitation of complementarities. Instruments that facilitate such exploitation should be the focus of policy action. The much larger challenge, however, is to design appropriate work environments and compensation packages that will attract talented young people to take up careers in academia. Doing so will alleviate the constraints on the availability of research-inclined faculty in academic institutions, a prerequisite for the formation of research-based links.

References

Adams, James D. 2001. "Comparative Localization of Academic and Industrial Spillovers." NBER Working Paper 8292, National Bureau of Economic Research, Cambridge, MA.

Arundel, Anthony, and Aldo Geuna. 2001. "Does Proximity Matter for Knowledge Transfer from Public Institutes and Universities to Firms?" SPRU Electronic Working Paper 73, Science and Technology Policy Research, University of Sussex, Sussex, U.K.

Athreye, Suma. 2001. "Agglomeration and Growth: A Study of the Cambridge Hi-Tech Cluster." SIEPR Discussion Paper 00-42, Stanford Institute of Economic Policy Research, Stanford, CA.

Basant, Rakesh, and Pankaj Chandra. 2003. "Inter-organization Linkages in the IT Industry in India: A Case Study of Telecom Technologies." In *The Context of Innovation in India: The Case of the IT Industry*, ed. Anthony D'Costa and Eswaran Sridharan, 193–219. London: Palgrave.

———. 2006. "Role of Educational and R&D Institutions in City Clusters: An Exploratory Study of Bangalore and Pune Regions in India." IIMA Working Paper, Indian Institute of Management, Ahmedabad, India.

Best, Michael H. 2000. "Silicon Valley and the Resurgence of Route 128: Systems Integration and Regional Innovation." In *Regions, Globalization, and the Knowledge-Based Economy*, ed. John H. Dunning, 459–506. Oxford, U.K.: Oxford University Press.

Branscomb, Lewis M., Fumio Kodama, and Richard Florida, eds. 1999. *Industrializing Knowledge: University-Industry Linkages in Japan and the United States*. Cambridge, MA: MIT Press.

Business World. 2003. "Potent Research." May 19, 44–48.

Geiger, Roger L. 2001. "Industrializing Knowledge: University-Industry Linkages in Japan and the United States." *Journal of Economic Literature* 39 (1): 165.

Lawson, Clive. 1999. "Towards a Competence Theory of a Region." *Cambridge Journal of Economics* 23 (2): 151–66.

Mani, Sunil. 2002. *Government, Innovation, and Technology Policy: An International Comparative Analysis*. Cheltenham, U.K.: Edward Elgar.

Morris, Sebastian and Rakesh Basant. 2005. "Role of Small-Scale Industries in the Age of Liberalization." Paper of the Policy Group on Trade and Industry of the Asian Development Bank, Asian Development Group, Bangkok.

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

CHAPTER 14

The Entrepreneurial University

The Idea and Its Critics

Elizabeth Garnsey

The literature on the new entrepreneurial university claims that academic science has been transformed into an economic as well as an intellectual endeavor and that because of widespread new developments, "the university itself becomes an entrepreneur" and the "traditional division between science and industry breaks down" (Etzkowitz 2002, 1). Policy makers have taken up a new agenda with an emphasis on technology transfer, control of intellectual property (IP), and promotion by the university administration of entrepreneurship among researchers and students (Shane 2005). Many of the contributions to this book describe policies designed to encourage such developments. But a reaction against this perspective and a rejection of its underlying assumptions have also

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This chapter explores issues raised at the World Bank Institute and Social Service Research Council Symposium on University-Industry Linkages, Paris, March 27, 2006, in particular those raised by authors whose papers are now chapters of this book: David Mowery (chapter 10), Weiping Wu (chapter 11), Poh-Kam Wong (chapter 12), and Rakesh Basant and Pankaj Chandra (chapter 13).

Research on issues raised in this chapter is underway (2006) as part of the U.K. Research Council's (ESRC-EPSRC) Innovation and Productivity Grand Challenge Project.

occurred. Mowery shows in chapter 10 of this volume that dissension has been voiced not only by traditionalists in defense of the old ways, but also among the principals assumed to be promoting the entrepreneurial university: technology-transfer offices in leading U.S. universities and corporate sponsors of university research.

Several studies (such as Bozeman 2000; Leitch and Harrison 2006) have identified a disconnection between policies favoring the prioritization of university IP and entrepreneurship and the underlying evidence that provides their rationale. They point to a gap between the full range of historical evidence and the simplified idea of the entrepreneurial university that has been promoted to and by policy makers. Identifying cause and effect is made problematic by the difficulty of achieving controlled comparisons and by the feedback loops of history through which effects become causes. An analogy exists with the linear model of innovation, long rejected by academics but still influential in policy circles. Building on contributions by Mowery (chapter 10), Wu (chapter 11), Wong (chapter 12), and Basant and Chandra (chapter 13) on university-industry relations in the United States, China, Singapore, and India, this chapter discusses a number of puzzles and missing pieces concerning the idea of the entrepreneurial university.

A New Area of Research

An expanding literature describes how universities are attempting to engage with the corporate world while sustaining their academic mission (for example, Etzkowitz and others 2000; Gibbons and others 1993; Shane 2005). This literature examines measures introduced by different university systems around the world with the aim of showing how the new mission proposed for the university and the practices to facilitate its accomplishment are associated with the emergence and success of university-industry links. Much of this work is predicated on the idea that the spread of the entrepreneurial-style university inevitably accompanies recognition of its benefits in the new knowledge economy (Etzkowitz and others 2000). The success of the United States in commercializing emerging technologies is attributed to factors highlighted in the entrepreneurial university literature. This success has led to attempts elsewhere to emulate what are taken to be critical features of U.S. university experience. Other factors have received less attention, notably the United States government's longstanding and substantial support measures in favor of small companies commercializing emerging technologies (Connell 2006).

A substantial body of research shows that control of university IP through licensing and spinoffs has been a minor strand among the multifaceted interactions between science and industry (Bozeman 2000; Cohen, Nelson, and Walsh 2002). David Mowery and colleagues have examined the historical evidence without using the normative lens of the entrepreneurial university. In chapter 10, Mowery summarizes developments from the 1980s. The Bayh-Dole Act of 1980 is usually taken as the watershed in providing universities with entitlement to IP from their research. The act provided congressional support for exclusive licenses between universities and industrial firms for the results of federally funded research. Mowery shows that activity of this kind was already under way before 1980 and that other types of university-industry links, effected through publishing, researcher training, consulting, and other conventional academic activities continued to be as important as ever.

How are the disparities between research evidence and policy formation to be explained? Is it possible that a consensual vision has emerged among practitioners? According to Fransman (2002, 9), "A Consensual Vision or cognitive framework shapes thinking and decision making. It consists of an interrelated set of beliefs embodied in assumptions and expectations which serve the purpose of making the world seem intelligible and therefore orienting decision making." A consensual vision may be only partially grounded in evidence, as was the one that gained prominence in the telecommunications industry around the turn of the millennium regarding future demand conditions in that industry, according to Fransman's evidence. A consensus of this kind emerges among practitioners when it provides a welcome message with an apparent though partial basis in facts and, above all, offers relatively simple solutions to complex problems. The idea of the entrepreneurial university suggested that a focus on patentable research and commercialization might solve pressing problems facing policy makers. The message that universities should transform themselves into entrepreneurial sources of intellectual property pointed to a new source of funding for resource-constrained universities and for governments seeking to contain the charge of higher education on public sector borrowing. The idea that university spinoff companies could be a basis for renewal of economies faced with the offshore relocation of their traditional industries was particularly welcome to policy makers pinning their hopes on the new knowledge economy as the solution to the threat of competition from globalization.

The new consensual vision of the entrepreneurial university, if it can be so described in the presence of dissent, did not emerge suddenly but was constructed over the past quarter-century in response to persistent problems. It rested in part on research suggesting that much critical knowledge was emerging outside the university. The merging of science and industry had been described by Gibbons, among others: "By contrast with traditional knowledge, which we will call Mode 1, generated within a disciplinary, primarily cognitive, context, Mode 2 knowledge is created in broader, transdisciplinary social and economic contexts" (Gibbons and others 1993, 1).

U.S. Experience

But the role of licensing and patenting has by no means been proven to be the critical factor in the U.S. success in commercializing emerging technologies in the last quarter of the 20th century. A number of studies have shown the importance of interindustry differences in this context. In particular, the life sciences are clearly in a unique position in having a direct effect, through patenting, on innovation in the biopharmaceutical area (Cohen, Nelson, and Walsh 2002). The promise of blockbuster drugs and of patentability of genetic discoveries has made such drugs and discoveries the source of most of the revenues that U.S. universities have obtained from patenting and licensing. Those universities with patents in the life sciences have reaped returns of a different order of magnitude from all other IP sources, though these cases are rare (chapter 10; Bozeman 2000). Emerging technologies are commonly treated as an undifferentiated high-tech category (Druilhe and Garnsey 2004), with the consequence that many researchers and policy makers have overlooked the strong contrasts between the life sciences and other emerging technology sectors.

An issue that has not been brought directly into the debate by either proponents or critics of the entrepreneurial university is the extent to which the commercialization of IT in the United States was shaped by defense priorities and expenditure during the Cold War. This process has been documented by other streams of research (for example, Lécuyer 2006; Lowen 1997; Segaller 1998). What was distinctive about research funded by the U.S. Department of Defense was that it aimed at supporting emerging technologies that could be used by the military, in contrast with the immature technologies typically emanating from university laboratories. Moreover, key technologies were not all proprietary to their developers; many remained in the public domain. Knowledgeable U.S. entrepreneurs were able to commercialize IT technologies for which lengthy early research and development (R&D) costs had already been met by federal grants (Connell 2006). This approach applied even in areas of IT not usually associated with defense funding, such as the personal computer and ancillary technologies. For example, the Pentagon provided extensive funding of key individuals involved in the Xerox Palo Alto Research Center, the source of many innovations by IT entrepreneurs (Fong 2001). Among the entrepreneurial IT companies that grew dramatically, such as Sun, Cisco, Electronic Data Systems, and Environmental Systems Research Institute Inc., were those from federally supported university departments.

The rapidity of the commercialization of IT advances was a direct consequence of U.S. Cold War policies (Segaller 1998); the advances' entrepreneurial character was unanticipated. Long-term funding channeled through leading university departments to able professors and their students, together with complementary policies, made possible the development and commercialization of technologies on the basis of public procurement and public domain IP (Mowery and Rosenberg 1998). As Edith Penrose put it in her authoritative book on firm growth, in "important new industries . . . there will be scope for the entry of new firms with the more favourably endowed earlier established ones soon obtaining a dominant position in the industry" (1959, 224). This pattern applies in particular in networked industries in which leading companies set the technology standards. The dominance of U.S. companies in global IT industries can be traced back to the large pool of IT entrants starting out early in the United States. Many had technologies relatively well developed through federal funding and founders with insider R&D knowledge. Those firms were in a much better position to achieve success (aided by skill and chance) than university spinoffs whose technologies require extensive private funding before even achieving market readiness. In the post–World War II United States, universities were part of a larger military-industrial and knowledge complex that supported enterprise and laid the basis for venture capital and private enterprise (Lowen 1997; Lécuyer 2006). Federal procurement support for early-stage companies commercializing emerging technologies has continued (Branscomb and Auerswald 2002). In 2003, for example, small businesses were awarded US$5 billion in R&D contracts by U.S. federal government departments, excluding direct grants (Connell 2006, 11).

Dissenting Voices from the Corporate Sector

IT and telecommunications companies in particular have not welcomed the university's new claims to IP in technologies arising from research funded by taxpayers. U.S. firms have accused universities of an unrealistic approach to the valuation and assertion of patent rights. Recent university policies have been described as a source of friction rather than as a facilitator of collaboration with industry, as shown by testimony of a manager from Hewlett Packard to the Subcommittee on Science, Technology and Space of the U.S. Senate Commerce Committee: "Large U.S.-based corporations have become so disheartened and disgusted with the situation they are now working with foreign universities . . . more than willing to offer extremely favorable intellectual property terms" (September 17, 2002, statement by Dr. R. Stanley Williams, cited by Mowery in chapter 10). In pioneering U.S. universities, as Mowery shows in chapter 10, considerable skepticism about the rationale for the new university technology-transfer model exists, and some universities are reversing earlier efforts to control IP.

A focus on managing university IP has the advantage for policy makers of avoiding confrontation with traditional ways of organizing the faculties of universities, which would arouse more broadly based opposition. European universities continue to prize narrow specialization within specific academic disciplines. Emulation of the U.S. university scene has not included producing multiskilled students; for example, humanities undergraduates in Europe often lack the required breadth of knowledge in IT or quantitative analysis. At a higher level, the systematic training of graduate students in science and engineering and other research-based programs in leading U.S. universities, funded through teaching assistantships, has been on a much larger scale than under either elitist or mass university systems in Europe. Those factors, together with the entrepreneurial culture of the United States, have produced streams of college-trained graduates who could recognize and exploit opportunities in emerging technologies (Best 1999). The major changes in academic culture and teaching structure required to move European universities in this direction would be a much greater challenge to policy than charging technology-transfer offices with managing university-sourced IP and offering optional classes in entrepreneurship. The former type of change would raise fundamental dilemmas about academic excellence, faculty autonomy, and the rationale for the university.

Use of Disruptive Knowledge by Incumbent and New Entrant Companies

A related set of puzzles concerns the reasons that corporations in many countries do not appear to seek university knowledge or to establish close relations with universities (Lambert 2003). However, incumbent corporations are often reluctant to introduce completely new technologies that both are costly to commercialize and threaten their established markets. Often, new entrant companies are the launchers of generic new technologies (Shane 2004). But relatively few new entrants will be successful in the first generation. Indeed, costs and uncertainty are among the deterrents to commercialization of knowledge among incumbent firms. The nature of entrepreneurial innovation is that it has a high rate of failure. John Kenneth Galbraith put it bluntly:

> There is no more pleasant fiction than that technical change is the product of the matchless ingenuity of the small man forced by competition to employ his wits to better his neighbor. Unhappily it is a fiction. Because development is costly, it follows that it can be carried out only by a firm that has the resources associated with considerable size. (Galbraith 1956, 86)

Because of the high costs and uncertainties of long-term development, universities cannot expect spinoffs with immature technologies to be a major source of revenues, as the U.K.'s *Lambert Review of Business-University Collaboration* recognized (Lambert 2003). Universities seldom gain directly from firms started by their current members. Yet Galbraith's restatement of Joseph Schumpeter's late thinking turned out to be unfounded. The knowledge generated in universities is subject not to the selection forces of the market but to the distinctive logic of the scientific method. Continually advancing knowledge (or neglected findings from earlier scientific knowledge) can be used to find unexpected solutions to commercial problems that cannot be reached by path-dependent routes in corporate R&D. New firm formation in the form of serial spinoff stimulates innovation in local economic activity. A high rate of recycling of knowledge occurs, with financial returns more likely among second- and third-generation companies that devise new applications for knowledge originating in the university and that build on cumulative local capabilities, so confounding the assumption that considerable size is a requisite for technical innovation (Garnsey and Heffernan 2005; Lécuyer 2006).

Gains from exploiting university technologies are recognized by elite technology-based companies that aspire to develop breakthrough technologies. Discontinuous innovations from universities may enable fruitful combinations of technology; for example, image reconstruction methods from astronomy may have applications in medical diagnostics. The hope of gaining access to such knowledge—in the face of costly specialization in R&D across the board—is what incites elite technology-based corporations such as Microsoft or GlaxoSmithKline to seek close links and even shared lab space with universities and their spinoff companies. This route to innovation is particularly attractive to pharmaceutical companies, which are prepared to pay a premium to keep a watching post on university and spinoff activity in the life sciences. One objective is to access new medical entities for profitable drugs.

But in most other sectors, companies are not sufficiently certain that major revenues will result from collaboration to be prepared to pay license fees and negotiate university IP obstacles. Moreover, as has been seen, in IT and telecommunications there is a history of public domain technology that has created expectations that such technologies will not have to be paid for over and above corporate taxation. This history may account in part for the hostility of established companies in IT and telecommunications to the new mission for the universities. These companies do not buy in to the new consensual vision, and their advocates are actively challenging this vision (Allott 2005, 2006).

University Policy Responses in India, Singapore, and China

Authors in this volume demonstrate a spectrum of adherence to the idea of the entrepreneurial university. The latest convert, the National University of Singapore, is zealous in its adherence to precepts of the new vision. The National University of Singapore now epitomizes the concept of the entrepreneurial university and a new thrust in the direction of commercialization for Singapore's university system, as explained by Poh-Kam Wong in chapter 12. Singapore has done more to scale up higher education and probably has the most extensive policies connecting industry and education of any place in the world. In comparison, allegedly entrepreneurial university reforms in many other places look like tinkering.

In India, the response to the new consensus coming from the West has taken a variety of forms, as shown by Rakesh Basant and Pankaj Chandra in chapter 13. Strong pressures exist to preserve the character of universities and the scientific excellence of research institutes such as the National Chemical Laboratory, which is part of the Indian Council for Scientific and Industrial Research. This system has been a premier source of research and training of researchers in India but has not spun out a single new company. It was recognized by 1971 in the United States that well-endowed public research institutes were contributing less to the commercialization of science than were universities (Cooper 1971). This contrast takes on a national dimension in countries where scientific research is funded primarily in public research institutes rather than in teaching universities. The role of research students and postdoctoral researchers in diffusing knowledge into the economy is a topic requiring further investigation.

In India, responses to the new consensual vision about the importance of licensing and spinoff range from lack of interest to enthusiastic espousal of the vision and recommendations that follow from it. The belief in the importance of preserving traditional strengths in teaching and basic research is confronted by the idea that these priorities are old-fashioned. But contributions of various kinds to the local economy are found in universities nurturing traditional priorities in research and teaching excellence. And an encouraging degree of diversity exists among the incubators and spinoff policies of the Indian Institutes of Technology.

Diversity is seen to a considerable degree in China, where campaigns to promote university-based research and university-industry links are under way as a result of recent reforms, as Weiping Wu explains in chapter 11. In China, the significant part that the state can play in enabling entrepreneurs to move knowledge-based technologies into practice is well recognized. The Chinese Ministry of Education understands that research and technological inventions require commercialization mechanisms if universities are to contribute to national and local economies. The way in which university-owned enterprises are run (to absorb surplus university personnel) and the intrusion of local authorities' agendas may hamper the Chinese drive to research excellence. But so massive is the commitment to higher education and scientific research today in China that major advances are to be expected in the quality and quantity of advanced training and research in that country. Moreover, the Chinese government is in a position to assist directly in the commercialization of emerging technologies thereby obviating the shortage of patient capital from private and institutional investors that has hampered commercialization of areas such as advanced materials and environmental technologies in the West. The Chinese government allows entrepreneurs to probe, prove, and market (such as in mobile payments) a technology and then creates or provides resources to a state-owned company (which may have university origins) to scale up the activity. This process resembles that by which large companies acquire pioneering entrepreneurial university spinoffs in the West.

The chapters on university-industry links in India, Singapore, and China demonstrate that industrial economies will not stay ahead of the developing economies simply by making claims to IP in university research, running entrepreneurship classes, and spinning off new companies. Universities in rising economies have been introducing these measures and more extensive ones to gain returns from knowledge. In particular, the rising economies have recognized the importance of scaling up the flow of students through graduate programs on the U.S. model and are training scientists and technologists on a massive scale at a time when students in the West are taking up science and technology in decreasing numbers (Sheehan 2005).

Conclusion

In summary, critics of the simple version of the entrepreneurial university thesis point out that the most important role of universities is to produce skilled people. Companies that engage with universities are often seeking recruitment opportunities. Commercializing knowledge emerging from university science labs requires long-term funding and innovative procurement policies (Connell 2006). Thus, an integrated set of policies is required in education, in R&D, in implementation of emerging technologies, and in regional policy. The exchanges between science and industry are complex, involving many iterations and enterprises of many different kinds. Undoubtedly, a need exists for greater openness between the two spheres, as advocated by proponents of the entrepreneurial university. The question that arises is whether prescribing the nature of the university's entrepreneurial role and advocating IP management are likely to promote the autonomy and ingenuity of innovators among research groups, entrepreneurial academics, research sponsors, and investors. Does this approach recognize that genuine conflicts of interest between science and commerce may persist (Merton 1942)? Does it illuminate the cumulative competence building and government support that stimulate the rise of new industry around science-based universities?

Contributions to this volume do much to challenge an oversimplified version of the entrepreneurial university and point to the need for further evidence. A critical perspective is needed to assess both the merits and the weaknesses of new policy priorities and to assist policy makers in developing countries to introduce appropriate measures.

References

Allott, Stephen. 2005. "People Not Ideas." *Prospect* (April) 17–18.

———. 2006. "From Science to Growth." City Lecture 2006, University of Cambridge, Cambridge, U.K., March 21.

Best, Michael. 1999. *The New Competitive Advantage: The Renewal of American Industry*. New York: Oxford University Press.

Bozeman, Barry. 2000. "Technology Transfer and Public Policy: A Review of Research and Theory." *Research Policy* 29 (4–5): 627–55.

Branscomb, Lewis, and Phil Auerswald. 2002. *An Analysis of Funding for Early-Stage Technology Development*. Report prepared for the U.S. Department of Commerce National Institute of Standards and Technology, Washington, DC.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh. 2002. "Links and Impacts: The Influence of Public Research on Industrial R&D." *Management Science* 48: 1–23.

Connell, David. 2006. "'Secrets' of the World's Largest Seed Capital Fund: How the United States Government Uses Its Small Business Innovation Research (SBIR) Programme and Procurement Budgets to Support Small Technology Firms." Centre for Business Research, University of Cambridge, Cambridge, U.K.

Cooper, Arnold. 1971. "Spin-offs and Technical Entrepreneurship." *IEEE Transactions on Engineering Management* 18: 2–6.

Druilhe, Céline, and Elizabeth Garnsey. 2004. "Do Academic Spin-Outs Differ and Does It Matter?" *Journal of Technology Transfer* 29: 269–85.

Etzkowitz, Henry. 2002. *MIT and the Rise of Entrepreneurial Science*. London: Routledge.

Etzkowitz, Henry, Andrew Webster, Christiane Gebhardt, and Branca Regina Cantisano Terra. 2000. "The Future of the University and the University of the Future: Evolution of Ivory Tower to Entrepreneurial Paradigm." *Research Policy* 29: 313–30.

Fong, Glenn R. 2001. "ARPA Does Windows: The Defense Underpinning of the PC Revolution." *Business and Politics* 3 (3): 213–37.

Fransman, Martin. 2002. *Telecoms in the Internet Age: From Boom to Bust to . . . ?* Oxford,U.K.: Oxford University Press.

Galbraith, John Kenneth. 1956. *American Capitalism*. Boston: Houghton Mifflin.

Garnsey, Elizabeth, and Paul Heffernan. 2005. "High-Technology Clustering through Spin-Out and Attraction: The Cambridge Case." *Regional Studies* 39 (8): 1127–44.

Gibbons, Michael, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott, and Michael Trow. 1993. *The New Production of Knowledge*: *The Dynamics of Science and Research in Contemporary Societies*. London: Sage.

Lambert, Richard. 2003. *Lambert Review of Business-University Collaboration*. London: Her Majesty's Treasury.

Lécuyer, Christophe. 2006. *Making Silicon Valley*: *Innovation and the Growth of High Tech, 1930–1970*. Cambridge, MA: MIT Press.

Leitch, Claire, and Richard Harrison. 2006. "Voodoo Economics or Entrepreneurial University? The Role of Spin-Out Companies in the Entrepreneurial System." School of Management and Economics Working Paper, Queen's University, Belfast, U.K.

Lowen, Rebecca. 1997. *Creating the Cold War University: The Transformation of Stanford*. Berkeley and Los Angeles: University of California Press.

Merton, Robert K. 1942 [1973]. "The Normative Structure of Science." In *The Sociology of Science: Theoretical and Empirical Investigations*, 267–78. Chicago: University of Chicago Press.

Mowery, David, and Nathan Rosenberg. 1998. *Paths of Innovation*: *Technological Change in 20th-Century America*. New York: Cambridge University Press.

Penrose, Edith. 1959 [1995]. *The Theory of the Growth of the Firm*. Oxford, U.K.: Oxford University Press.

Segaller, Stephen. 1998. *Nerds 2.0.1.: A Brief History of the Internet*. New York: TV Books.

Shane, Scott. 2004. *Academic Entrepreneurship*. Cheltenham, U.K.: Edward Elgar.

———, ed. 2005. *Economic Development through Entrepreneurship*: *Government, University, and Business Linkages*. Cheltenham, U.K.: Edward Elgar.

Sheehan, Jerry. 2005. "OECD Science, Technology, and Industry Outlook 2004." *Issues in Science and Technology* (spring): 1–6.

PART IV

Corporate Strategies of Multinational Corporations and Small and Medium Enterprises

CHAPTER 15

Beyond Absorptive Capacity

The Management of Technology for a Proactive Corporate Strategy toward University-Industry Links

Fumio Kodama, Shingo Kano, and Jun Suzuki

In their seminal article, Cohen and Levinthal (1990) discussed the notion of "absorptive capacity," illustrating an organization's knowledge deployment for creating innovative capabilities. They defined *absorptive capacity* as a firm's ability "to recognize the value of new, external knowledge, assimilate it, and apply it to commercial ends" (Cohen and Levinthal 1990, 128). Following the original conceptualization of absorptive capacity, a significant body of research has linked it to organizational learning and to improved performance-level outcomes. Support for these relationships has been validated in research and development (R&D) environments (Chen 2004; Lane and Lubatkin 1998; Stock, Greis, and Fischer 2001), in small and medium enterprise (SME) or start-up scenarios (Deeds 2001; Liao, Welsch, and Stoica 2003), and in the context of collaborative organizational forms (Shenkar and Li 1999; Tasi 2001). Drawing on the view of a firm's dynamic capabilities, Zahra and George (2002) showed how absorptive capacity determines the gap between a firm's potential and its realized capacity to innovate.

Knowledge management is a topic of current prominence in the entrepreneurial management of technology research that reinforces the arguments for the absorptive capacity concept. We will argue, however, that case studies from Japan are going beyond a simple notion of absorptive capacity—that is, toward a more *proactive* role played by receiving units. Our assumption is that entrepreneurship thrives when innovators respond proactively and appropriately to their informational environment. Technology transfer imposes ambiguity and uncertainty such that receiving firms must deploy knowledge-based responses to effectively meet task objectives. We will demonstrate, furthermore, that these knowledge-based responses are derived from the timely installation of simulation platform and from the organizational designs of firms, which proactively stimulate absorptive capacity.

Modeling a Proactive Absorption Mechanism: University-Industry Link Morphology

Technology transfer occurs whenever systematic, rational knowledge developed by one group or institution is embodied in ways of doing things by other groups or institutions (Brooks 1966). This definition implies a distinct relocation of knowledge between autonomous entities, requiring the existence of both a "supplier" and a "receiver" of new technology. It further implies that relocation is "successful," or "effective," only when the transfer is complete and adds value to a receiver's competencies.

We have argued that technology transfer is most successful when applied within a receiver-active paradigm, in which receivers engage aggressively in the transfer process (Kodama 1993; Kodama and Morin 1993). The receiver-active paradigm is analogous to the more familiar technology-push/market-pull description of how technology is transferred. In essence, this model holds that successful technology transfer largely depends on the receiver rather than the supplier. That is, aggressive receivers can obtain technology from passive suppliers, but passive receivers are unlikely to obtain technology from even the most aggressive suppliers. Fundamental to the receiver-active perspective is the notion of processing relevant information. Effective technology transfer stems from a receiving entity's acquisition of critical information not only from the technology supplier but also from other sources both inside and outside its organizational boundaries. This perspective is reinforced by research substantiating links between successful innovation and early involvement of lead users in product development projects (von Hippel 1988).

In this section, we formulate the process of proactive absorption so as to draw several policy implications. Science-based industries, such as biotechnology and information science, are characterized by the following features (Kano 1999):

- *Scientific research is a direct source of innovation*. The companies in the science-based industries frequently need to secure relationships with relevant academic institutions.
- *Understanding of the applicability of research is limited*. Because the trends in scientific research are constantly changing, only a handful of people can foresee whether the embryonic basic research in question would be industrially applicable.
- *Fuzzy differentiation exists between basic science and application*. Companies engaged in science-based industries find it hard to set boundaries between the basic science and application and, therefore, may not be able to determine the suitable extent of in-house fundamental research. This fuzziness also lowers the probability of successful outsourcing.

These characteristics of science-based industry call for enhanced university-industry links (UILs) and, at the same time, entail difficulties in their rational design. The incomplete understanding of embryonic technology, the vague boundaries between science and application, and the cost of research all act as barriers to the beneficial association of businesses and academic researchers and sometimes lead to excessive investment in basic research.

They may also be responsible for the birth of a large number of venture businesses dedicated to R&D. Existing in the gap between academic institutions and established private companies, these businesses take over research projects from universities and other entities and act as bridge organizations for product development and marketing. Such businesses are often found in biotechnology fields such as genetics for gene therapy and human genome studies. Science-based industry, as represented by these examples, relies for its existence on scientific research results for which industrial applicability may not be easily recognized. For established businesses, this technology transfer may upgrade emerging innovations either through the businesses' own efforts or in collaboration with universities. Universities are a fundamental resource for science-based industry, which must coordinate resource allocation among universities and companies involved in the innovation process.

At issue is what kind of coordination mechanism would best enhance UILs. In an analysis of coordination mechanisms, the premise is that very few employees in the recipient company will be able to recognize potential innovation sources. This premise invokes the concept of "bounded rationality," which is discussed by the researchers of comparative institutional analysis: firms seeking links with universities attempt to select sensible approaches, but because of their partial understanding, they are unable to optimally coordinate the process.

To better understand resource coordination issues in science-based industry, we first introduce a basic problem of mismatches that exist between universities and industrial firms. Next we consider the general concept of an "innovation agent," representing the function that minimizes mismatches, intermediates both sides, and executes R&D activities according to the phase of innovation through appropriate management. Finally, we examine the classification of innovation agent forms and features to analyze UIL morphology.

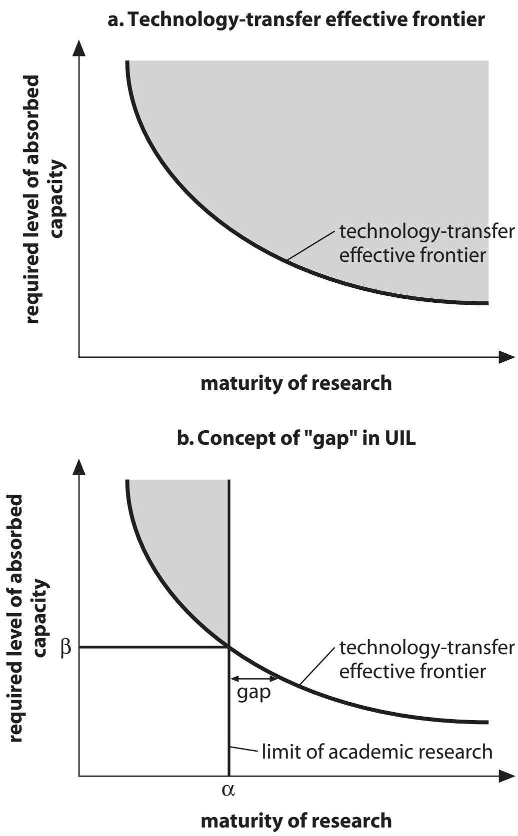
The point of departure is the "recognition gap" between university and company research. At the heart of UIL problems for firms is how to deal with that gap. Generally, the more creative and original university research, the fewer the researchers in this field and the lower the probability that the company has the personnel who can recognize the value of the research. In other words, the firm's evaluation capacity will most likely be insufficient, and research that exceeds their evaluation capacity cannot be absorbed through channels such as collaborative research and licensing.

What is rational behavior by the company in evaluating a university's research? First, the criterion for importing technologies from outside the firm is the technologies' relevance to the firm's core businesses. Second, the firm must comprehend the contents of the technology if it is to be effectively integrated with in-house technology. Those two components constitute the firm's absorptive capability.

If the research is at an embryonic stage, the firm will have difficulty ascertaining its relevance to its businesses and comprehending its scientific contents. Therefore, the lower the maturity of research, the higher the level of absorptive capability needed by the firm. Figure 15.1 (panel a) depicts the relationship by putting the maturity of academic research on the *x*-coordinate and the firm's required level of absorptive capacity on the *y*-coordinate. Given the maturity stage of academic research, the level of absorptive capacity can be determined as a threshold value, below which technology transfer is unlikely to be realized. These threshold values constitute a continuously decreasing function. We can call this line the *technology-transfer effective frontier*. In other words, the shaded region is the area where technology transfer occurs.

After the framework of technology transfer is established, we can ask why the gap exists. The limit to university research is defined by the maturity coordinate, beyond which research is no longer conducted in the academic institution. This limitation of university research can be drawn as a vertical straight line that intersects at the value of α in the *x*-coordinate (figure 15.1, panel b). Then, the shaded area surrounded by the limit line of university research and the technology-transfer effective frontier is the area

Figure 15.1. Technology-Transfer Effective Frontier



Source: Kano 2001.

where technology transfer from university to industry occurs. For funding by the public sector as basic research, the research should be of a level of maturity lower than α in the x-coordinate. Those firms whose absorptive capacity is below β, the value of the y-coordinate intersected by the value of α in the x-coordinate, cannot absorb the research, even if the subject of the research is within the limit of their businesses.

Even if the university research progresses further, the collaboration between the university and the firm might never occur for research located below the technology-transfer effective frontier. This situation is denoted by the "recognition gap," and the distance toward the frontier can be used as the degree of the gap.

Now we will examine the classification of innovation agent forms and features so as to delineate UIL morphology. The issue for corporate strategy and management is how to develop collaboration so as to extend university research and commercialize it. Three types of bridging activities can be defined:

- *Type I bridging* exists when the company can absorb science directly from the university through joint research. Most Japanese UILs belong to this type of collaboration. The corporate strategic problem is how to enhance the firm's absorptive capacity.
- *Type II bridging* exists if a gap between the university and an industrial firm must be bridged by an intermediary such as a start-up company. A start-up unit has to extend the academic research to bring it within the firm's absorptive capacity. An in-house venture unit within a firm can perform this intermediary function if it is assured substantial autonomy.
- *Type III bridging* exists if the extension of the research will never lead to the business domain of existing companies. Therefore, new industries and firms have to be created to absorb those areas of research.

Technological Platform for Assimilating New Science: TOTO Ltd.

What is the appropriate corporate strategy for making type I bridging possible? A case study of TOTO Ltd., a Japanese manufacturer of sanitary wares, provides us with an excellent example of how the ability for absorbing new sciences regenerated its main business in a substantial way.

TOTO Ltd. sought to commercialize a toilet system in which organic compounds are decomposed biochemically, a technique that relies on the photocatalytic properties of titanium dioxide discovered by researchers at the University of Tokyo. This development relied on scientific findings published in three separate papers in *Nature* magazine (Fujishima and Honda 1972; Kawai and Sakata 1980; Wang and others 1997). More interestingly, the last paper was coauthored with TOTO researchers who had discovered that titanium dioxide is also superhydrophilic (water attracting).

Recognizing the Value of New Science

Since 1978, TOTO had been developing the key technology of analysis and synthesis of bad smell as the results of their persistent in-house scientific endeavor. Many kinds of bad smells accompany human living, such as toilet, sweat, tobacco, or garbage odors.

The early construction of a smell simulator provided TOTO researchers with a kind of experimental platform for appreciating, assessing, and absorbing new smell-related technologies developed at the University of Tokyo. Dr. Akira Fujishima at the University of Tokyo discovered the unique photocatalytic properties of titanium dioxide, which subsequently came to be known as the Honda-Fujishima effect, and published a paper in Japan in 1969 (Fujishima and Honda 1972).

Titanium dioxide produces free radicals that are very efficient oxidizers of organic matter. The decomposition property of organic compounds had been discovered by Tomoji Kawai and Tadayoshi Sakata at National Institute of Molecular Sciences, and it was published by *Nature* in 1980 (Kawai and Sakata 1980). Meanwhile, Kazuhito Hashimoto, who had entered this institute in 1980 as a junior researcher after graduating from the School of Science at the University of Tokyo, joined this research group and published several papers on the subject (Hashimoto, Kawai, and Sakata 1983a, 1983b). In 1989, he moved to the School of Engineering at the University of Tokyo in order to join Fujishima's lab. There, he had the idea of using titanium dioxide as a photocatalyst for the decomposition of organic compounds (Hashimoto, Kawai, and Sakata 1984; Sunada and Hashimoto 1998). In 1991, TOTO initiated a contact with the University of Tokyo research team to develop photocatalytic tiles coated with titanium dioxide. The coating technology was developed by TOTO with scientific advice from the University of Tokyo. In 1994, those tiles were brought to market. The tiles possessed antibacterial properties, meaning that any bacteria on the surface were eliminated by the titanium dioxide, which also prevented yellowing and controlled odors. These tiles were a big hit with consumers and became the first step toward the practical application of photocatalyst technology.

Discovering Another Property

The continuing collaborative research between the Fujishima lab and TOTO Ltd. resulted in the discovery of another unique character of titanium dioxide, the photo-induced superhydrophilic property. This property was first discovered by TOTO researchers in collaboration with University of Tokyo researchers (Wang and others 1997). The property is important for the self-cleaning effect of titanium dioxide–coated tile, because it helps rinse away chemical compounds. Without the discovery of the superhydrophilic property, the practical application of photocatalytic titanium dioxide could not have been achieved as we see it today. On the basis of those technologies, TOTO has developed many kinds of sanitary products and self-cleaning products, such as exterior ceramic tiles (in 1996) and a sophisticated active deodorizer (in 2001).

In summary, a firm's absorptive capacity is not simply the sum of the absorptive capacities of its employees, and it is distinctly organizational. Most research on understanding the sources of a firm's absorptive capacity has focused on the structure of communication between the external environment and the organization, including the existence of gatekeepers and their related roles (Allen 1966). Absorptive capacity refers not only to the acquisition or assimilation of information by an organization but also to the organization's ability to exploit it.

Absorption by Mainstream Industries

The superhydrophilic property of titanium dioxide has also been exploited by the auto and engineering industries. The property is used for self-cleaning and antifogging of the side mirrors of automobiles so that the side mirror can perform its function even in heavy rain. The property is important for the glass industry, because it maintains the view through glass windows both during and after rain. Several examples of absorption by engineering industries could be mentioned.

TOTO has obtained four basic patent applications of the superhydrophilic properties and many other patents. To license out the basic patents of superhydrophilic property to other industries, TOTO established a licensing company, TOTO Frontier Research Co. Ltd., in 1997. The first licensee was Nissan Motor Co., and the first foreign licensee was the German company DSCB, in 2000. As of 2004, the number of licensees exceeded 60. The market size of photocatalysis products is estimated to be ¥50 billion.

What can be learned about UILs from this case study? The links of universities with mainstream industries are not necessarily direct, but can be indirect through peripheral industries. This case study clearly shows that a chain of supporting discoveries is often needed for a discovery made in universities to achieve commercial success.

Organizational Design for Inserting an Intermediary Function: Takeda Chemical Industries

In type II bridging in a large existing company, how can we place a start-up unit in a proper way? This question is a problem of organizational design for inserting an intermediary between an academic institution and central research laboratories (CRLs) of large enterprises. We will describe how Takeda launched its new independent research laboratory specializing in basic research on then-emerging genetic engineering (GE) and protein engineering (PE) technologies, despite the existence of Takeda's large established CRL.

Takeda is the largest pharmaceutical firm in Japan. It was founded as a small medicine wholesaler over two centuries ago. It was incorporated in 1925 and subsequently listed on the Tokyo and Osaka stock exchanges in 1949. Takeda's nonconsolidated net sales are about ¥760 billion (fiscal year 2000). Domestic sales account for 71 percent of this amount. In addition, the firm has long been a top-ranking patent applicant among Japanese pharmaceutical firms.

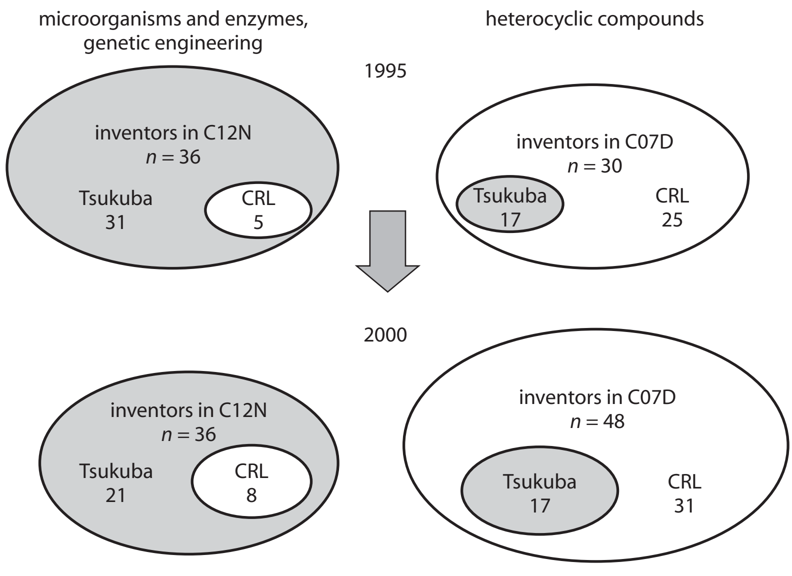
In the 1940s, Takeda began exploratory research on antibiotics and synthetic folic acid in addition to vitamins C and B_1. It also conducted research on penicillin, which it started manufacturing by quasi-synthetic (with fermentation) technology in 1948. During the 1960s and 1970s, Takeda developed some novel antibiotics, including third-generation cephalosporins. In addition, Takeda succeeded in launching new businesses with synthetic sodium glutamate and a mixture of the purine derivatives extracted from yeast. The important generic technologies underlying these successes were known as *synthetic organic chemistry* and *microbe fermentation*.

In 1974, Stanley Cohen and Herbert Boyer applied for the famous gene-splicing patent, and by the 1980s, gene research had taken off in Japan as well. In addition to genetic engineering, research into receptors and ligands and bioactive substances had begun in the early 1980s and advanced significantly with the emerging GE and PE technologies. In 1988, Takeda launched its research laboratory specialized in basic research on orphan receptors (receptors with unknown functions) in Tsukuba. As Japan's largest science city, Tsukuba is where almost all the national research labs, together with national universities, are located (Suzuki and Kodama 2004). Takeda launched the laboratory to enhance the research productivity through competition and cooperation between the central and the new research laboratories.

Takeda's case appears to represent a model of technology diversification by conducting research on exotic technologies and fusing them with existing technologies. At the generic technology level, Takeda devised and sought GE, PE, and genome informatics technologies. Those technologies were then fused with core technologies such as organic synthesis and fermentation. Did such fusion really occur? We have tried to show this process by investigating patent applications made by two Takeda labs from 1995 to 2000 (see figure 15.2). The patents in the area of GE and PE are represented by patents in International Patent Classification category C12N (microorganisms/enzymes, genetic engineering), and those in the area of organic chemistry are represented by C07D (heterocyclic compounds).

As shown in the figure, in 1995, 31 of Takeda's total of 36 patents in category C12N, representing GE and PE, were filed by researchers at the lab in Tsukuba, whereas only 5 patents were filed by researchers at CRL.

Figure 15.2. Occurrence of Fusion at Takeda of GE and PE Technologies with Organic Chemistry Technologies



Source: Kodama 2004.

In the category C07D, representing organic chemistry, in contrast, 25 of Takeda's 30 patents were filed by CRL researchers, whereas only 5 patents were filed by Tsukuba researchers. In 2000, however, the distinction between Tsukuba and CRL had become less clear cut. The number of C12N patent applications by CRL researchers increased to 8 of Takeda's 29 patents, while the number of C07D patent applications by Tsukuba increased to 17 of Takeda's 48 patents.

In terms of share of each laboratory in Takeda's total patents filed for GE and PE technologies, Tsukuba lab's share decreased from 86 percent in 1995 to 72 percent in 2000, while Tsukuba's share in the field of organic chemistry increased from 17 percent in 1995 to 35 percent in 2000. These statistics indicate how the GE and PE technologies invented by the new research unit were fused with core technologies such as organic synthesis and fermentation owned by CRL, and vice versa.

Conclusion: Proactiveness, Reciprocity, and Organizational Design

The TOTO case study suggests that a firm plays a more proactive role in technology transfer than the role implied by the term *absorptive capacity*. We demonstrated that successful technology transfer depends largely on the efforts of the receiving firm rather than on the active marketing of research by the university.

The case study also highlights the sequence in the receiver-active paradigm: basic research in TOTO's labs produced the key technology of the testing platform and made possible the effective monitoring of research conducted outside the firm; by using the smell simulators, TOTO's researchers could evaluate the technology developed as an outcome of applied research done elsewhere and thereby determine the best direction for TOTO's own applied research. Next, TOTO researchers made a scientific discovery that was not a part of the prior collaboration with the university. This scientific accomplishment facilitated cooperation with the scientific community, composed of universities and other science organizations, and this cooperation produced further discoveries, which supported the product development process.

The case study also underscores the importance of proactive firm strategies in establishing UILs:

- A testing platform should be developed early enough for the firm to grasp the opportunity to use future scientific discoveries.

- The scientific discovery is very often thought to be for purposes that can be vastly different from those that finally turn out to be effective. Several scientists can be involved in each shift in areas of application, and the mobility of scientists can play a crucial role.
- The UIL can be reciprocal and is not necessarily a one-way street from the university to the industrial firm.

Detailed data and a firm's technological history provide evidence that diversification of the core technology can generate new technological trajectories adjacent to the existing core. Generated technological trajectories sometimes link directly to new product development and market entry but sometimes affect new products indirectly by generating other technological trajectories. Innovative Japanese firms have had sustaining technologies but also some disruptive technologies (Christensen 1997). They have sometimes dramatically transformed their main business links—for example, Canon went from camera to printer, Toyota went from looms to autos, and Sharp went from stationery to electronics.

Takeda's development of technology from fermentation to quasi-synthesis and pure synthesis of antibiotics enabled the firm to consistently provide an effective and broad spectrum of products. Its successful core technology diversification into adjacent fields was undertaken with the explicit goal of business diversification. Takeda's expansion into remote technology domains, such as food products or industrial chemicals production, proved unsuccessful. However, exotic technologies, like, in Takeda's case, GE and PE, can sometimes evolve along new and commercially profitable trajectories.

References

Allen, Thomas J. 1966. "Performance of Information Channels in the Transfer of Technology." *Industrial Management Review* 18 (1): 87–98.

Brooks, Harvey. 1966. "National Science Policy and Technology Transfer." In *Proceedings of a Conference on Technology Transfer and Innovation*. Washington, DC: National Science Foundation.

Chen, Chung-Jen. 2004. "The Effect of Knowledge Attribute, Alliance Characteristics, and Absorptive Capacity on Knowledge Transfer Performance." *R&D Management* 34 (3): 311–22.

Christensen, Clayton. 1997. *The Innovator's Dilemma.* Boston: Harvard Business School Press.

Cohen, Wesley M., and Daniel A. Levinthal. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35: 128–52.

Deeds, David. 2001. "The Role of R&D Intensity, Technical Development and Absorptive Capacity in Creating Entrepreneurial Wealth in High Technology Start-Ups. *Journal of Engineering and Technology Management* 18 (1): 29.

Fujishima, Akira, and Kenichi Honda. 1972. "Electrochemical Photolysis of Water at a Semiconductor Electrode." *Nature* 238: 37.

Hashimoto, Kazuhito, Tomoji Kawai, and Tadayoshi Sakata. 1983a. "Efficient Hydrogen Production from Water by Visible Light Excitation of Fluorescein-Type Dyes in the Presence of a Redox Catalyst and a Reducing Agent." *Chemistry Letters* 12 (5): 709–12.

———. 1983b. "Hydrogen Production with Visible Light by Using Dye-Sensitized TiO_2 Powder." *Nouveau Journal de Chimie* 7: 249.

———. 1984. "Photocatalytic Reactions of Hydrocarbons and Fossil Fuels with Water. Hydrogen Production and Oxidation." *Journal of Physical Chemistry* 7: 4083.

Kano, Shingo. 1999. "The Innovation Agent and Its Role in University-Industry Relations." In *Industrializing Knowledge: University-Industry Linkages in Japan and the United States*, ed. Lewis Branscomb, Fumio Kodama, and Richard Florida, 365–84. Cambridge, MA: The MIT Press.

———. 2001. "Introduction and Comparison of Technology Transfer Models in University-Industry Relations: The Concept of Technology-Transfer Effectiveness Frontier and Its Application." *Business Model* (Electronic Journal of Japanese Society for Business Model) 1 (1): 1–10.

Kawai, Tomoji, and Tadayoshi Sakata. 1980. "Conversion of Carbohydrate into Hydrogen Fuel by a Photocatalytic Process." *Nature* 286: 474–76.

Kodama, Fumio. 1993. "Receiver-Active Paradigm of Technology Transfer." In *New Perspectives on Global Science and Technology Policy*, ed. Sogo Okamura, Fujio Sakauchi, and Ikujiro Nonaka, 229–45. Tokyo: Mita Press.

———. 2004. "Toward a Theory of University Industry Linkages." [In Japanese.] *Technology and Economy* (July): 44–53

Kodama, Fumio, and William Morin, chairs. 1993. *Report of the U.S.-Japan Technology Transfer Joint Study Panel*. Document PB93-182921. Prepared by the U.S. Department of Commerce, Technology Administration, and submitted to the Joint High Level Committee of the U.S.-Japan Science and Technology Agreement. Washington, DC: U.S. Department of Commerce.

Lane, Peter, and Michael Lubatkin. 1998. "Relative Absorptive Capacity and Interorganizational Learning." *Strategic Management Journal* 19 (5): 461–77.

Liao, Jianwen, Harold Welsch, and Michael Stoica. 2003. "Organizational Absorptive Capacity and Responsiveness: An Empirical Investigation of Growth-Oriented SMEs." *Entrepreneurship Theory and Practice* 28 (1): 63–85.

Shenkar, Oded, and Jaitao Li. 1999. "Knowledge Search in International Cooperative Ventures." *Organization Science* 10 (2): 134–44.

Stock, Gregory, Noel Greis, and William Fischer. 2001. "Absorptive Capacity and New Product Development." *Journal of High Technology Management Research* 12 (1): 77.

Sunada, Kayano, and Kazuhito Hashimoto. 1998. "Bactericidal Effect Using TiO_2 Photocatalysis." *Journal of Antibacterial and Antifungal Agents* 26 (11): 611–20

Suzuki, Jun, and Fumio Kodama. 2004. "Technological Diversity of Persistent Innovators in Japan: Two Case Studies of Large Japanese Firms." *Research Policy* 33: 531–49.

Tasi, Wenpin. 2001. "Knowledge Transfer in Intraorganizational Networks: Effects of Network Position and Absorptive Capacity on Business Unit Innovation and Performance." *Academy of Management Journal* 44 (5): 996–1005.

von Hippel, Eric. 1988. *The Sources of Innovation*. New York: Oxford University Press.

Wang, Rong, Kazuhito Hashimoto, Akira Fujishima, Makoto Chikuni, Eiichi Kojima, Atsushi Kitamura, Mitsuhide Shimohigoshi, and Toshiya Watanabe. 1997. "Light-Induced Amphiphilic Surface." *Nature* 388: 431–32.

Zahra, Shaker A., and Gerard George. 2002. "Absorptive Capacity: A Review, Reconceptualization, and Extension." *Academy of Management Review* 27 (2): 185–203.

CHAPTER 16

Corporate Strategies in University-Industry Links in France

Jean-Jacques Duby

In France, as in any other country, universities have three missions regarding knowledge: knowledge transmission (that is, education), knowledge production (that is, basic research), and knowledge sharing (that is, research applied to industrial, economic, or social needs). Corporate strategies governing university-industry links (UILs) are naturally tailored for those three missions, as is reflected in this chapter.

But this general picture needs to be fine-tuned to take into account three particularities of the French education, research, and innovation system:

- *The split between universities and* grandes écoles. Whereas French universities date to the 13th century, the *grandes écoles* were created in the 18th century by the French government to educate the elite technical civil servants that it needed. Initially, the *grandes écoles* offered education in the fields of military and civil engineering. Today, a vast majority of French industry leaders are *grandes écoles* alumni, which will definitely affect corporate relations with the universities. The two main criteria that separate universities and *grandes écoles* are selection and orientation: *grandes écoles* select students and are vocationally oriented; universities do not select students and are not vocationally oriented. (Although some universities have started introducing vocational and selective curricula, they are still a minority.) Another criterion is tuition fees: they are close to nil in universities, more significant in *grandes écoles*, and much higher in business *grandes écoles*. Although there are more *grandes écoles* than universities (250 compared with 80), fewer students attend *grandes écoles* than universities (168,000 compared with 1.5 million). Each *grande école* produces at most a few hundred graduates a year, and many graduate fewer than a hundred students a year.

- *The superposition of universities and public research organizations.* Among the 200,000 public researchers in France, two-thirds work in universities and one-third in public research organizations, such as the National Scientific Research Center (Centre National de la Recherche Scientifique, or CNRS); the National Institute for Health and Medical Research (Institut National de la Santé et de la Recherche Médicale, or INSERM) for biology and medicine; the Atomic Energy Commission (Commissariat à l'Energie Atomique, or CEA) for nuclear research; and the National Space Study Center (Centre National d'Études Spatiales, or CNES) for aerospace. Furthermore, those research organizations select the best university laboratories in their domain and "associate" them; they supplement the funding and staffing of these university labs with their own resources. One consequence is that universities find having their own research strategy very difficult, because their best units are, so to speak, preempted by public research organizations. A second consequence is to make the French public research landscape particularly complex. Some laboratories—particularly the best ones—may "belong" to several institutions: a university, an institute, and one or two research organizations. This complexity also affects corporate UIL strategies, because large corporations find dealing directly with CNRS or INSERM simpler and more efficient, so they bypass universities.
- *Pervasive state involvement and control.* The French tradition of Jacobinism is particularly strong in education and research. More than 90 percent of tertiary education expenses are covered by the public budget, compared with less than 60 percent for the average of Or-

ganisation for Economic Co-operation and Development countries. Although this statement may be a tautology, public research organizations derive less than 6 percent of their budget from private resources. Furthermore, all degrees granted by any university or *grande école* have to be ratified or officially registered by the government, and the allocation of public funds to the public research institutions is decided yearly by the state administration. All those reasons contribute to minimizing any leverage that industry might have in the governance of public research and higher education. The recent importance given to local authorities (the 21 *régions*, each of which encompasses several of Napoleon's *départements*), which now support research and development (R&D), added one more level of public government—not necessarily in full agreement with the national level.

Distinctive French characteristics are fewer on the industry side. As in any other country, when one is discussing UILs in France, distinguishing among three types of small and medium enterprises (SMEs) is convenient: those that *produce* advanced technology, those that *use* advanced technology, and the *others*. The first two categories need to be able to monitor the technological state of the art, to find technologically up-to-date new hires, and to maintain the technical and scientific knowledge of their personnel. In addition, SMEs in the first category need advanced technological and scientific support from university laboratories to feed their innovation process and to help resolve their technological problems. Generally, only SMEs of the first category have direct links with universities. However, in several industries, such as engineering, textiles, or construction, SMEs of the second category benefit from another French particularity, the Centres Techniques Industriels, or industry technical centers, which perform applied research under governance from the industry employers' federations with funds provided by mandatory contributions from each enterprise in the industry. Some industry technical centers have several hundred researchers and enjoy the same kind of relations with universities and public research institutions as any large advanced-technology multinational corporation (MNC), and they make sure their subscribers benefit from those relations.

With this information as background, I now consider how French enterprises manage their relations with universities in the three areas of knowledge transmission, knowledge production, and knowledge sharing, and I conclude with an overview of French government policies regarding UILs and their most recent evolution.

Knowledge Transmission

Every French enterprise can be considered a customer of the universities and *grandes écoles* in the tertiary education system; enterprises hire young graduates and, in some cases, buy continuous education services from them for mid-career training, for example. In the vast majority of cases, enterprises are passive customers, particularly for hiring: most hire graduates from a university without going to the university to attract or locate promising students. MNCs and technology-producing SMEs have a more proactive role, especially vis-à-vis the *grandes écoles*.

Most MNCs scout for talent, particularly in the *grandes écoles*, more particularly in the top 10 *grandes écoles*, and even more particularly in the *grandes écoles* from which the MNC executives graduated. They develop relations with student associations, through campus representatives, generally alumni who help sponsor student social activities, find internships, and so on. Such relationships also exist with the top 10 universities, although less frequently, because the universities' "production" of graduates is much less of a constraint. Advanced-technology SMEs cannot afford campus representatives, but they often have close relations with their founder's alma mater, be it a university or a *grande école*.

The next level of relationship is for an enterprise to take part in the education process. It may do so by cooperating in defining the curricula, by providing part- or full-time faculty members, and, of course, by providing internships. This level is mostly restricted to *grandes écoles*, given that the universities are rather jealous of their independence from industry and "big capital." In some *grandes écoles*, more than one-third of the courses may be given by scientists or managers from industry. Also, some *grandes écoles* have set up advisory bodies such as curriculum councils, on which school faculty and industry representatives work together to define school curricula. More recently, some *grandes écoles* have created professorships funded by private companies. This new trend started at business schools and is now spreading to engineering schools. The most dynamic enterprises are actively engaged in such relations.

The last level of university-industry relationship is that of governance. In France, the governance of universities is defined by law: the law sets the composition of all universities' boards of directors, and only a few seats are available for industry representatives. Furthermore, those representatives are appointed by the minister, which obviously limits the appointees' representativeness, if not their independence. French university governance is far from the board of regents model. French *grandes écoles* are freer to define their governance. Even in public *grandes écoles*, industry representatives have significant weight within the board of directors, and they are often nominated by industry and then appointed by the government. As for *grandes écoles* with private status, their directors are often directly appointed by industry. Moreover, when a significant part of the budget of the *grande école* comes from industry sources, industry may be in the driver's seat, as is the case, for instance, with Supélec, the leading French school in electrical and computing engineering, which is governed by a troika composed of the electrical, electronic, and communications industries; the software industry; and the power industry—under supervision, of course, of the French government (ministers of education, research, industry, and defense). One should mention here the creation of the first academic foundations by some of the top *grandes écoles*. Funded by donations from MNCs or rich alumni, these foundations do not yet represent a sufficiently sizable proportion of the schools' resources, but they reflect a long-range strategy on the part of both the *grandes écoles* and the MNCs eventually to become important enough to play a role in governance. In 15 or 20 years, some *grandes écoles*, more likely private than public, probably will be governed by a board of trustees.

Knowledge Production

In France, 57 percent of the national R&D is funded by industry, and the remaining 43 percent by the public budget. Industry's part in R&D funding is thus lower in France than in the European Union or the United States (65 percent) or than in Japan (73 percent). One could say that, in France, industry is more dependent on public research than it is in other industrial countries. Yet a recurrent problem in France is the inefficiency of industry-university research cooperation, beginning with knowledge production and becoming progressively worse with knowledge engineering.

In the early 1980s, the French government started asserting the political importance of promoting UILs. Since then, with the help of the government, MNCs and SMEs have developed numerous tools to cooperate with universities:

- Cofinanced PhD theses on industry-defined research topics, with a matching contribution of public money
- Common laboratories shared by a public research organization (mostly CNRS) and an enterprise

- Public research projects funded by an industry on subjects defined by the industry
- Appointment of private industry researchers as associate research staff members in public laboratories
- European cooperation projects with several enterprises and research institutions from different European countries, partly funded by the European Union

Those tools, however, are plagued with many administrative difficulties, such as the following:

- *Multiplicity of public stakeholders.* As mentioned above, signing a cooperation contract with a laboratory might require an agreement with several public institutions, universities, or research organizations, plus regional authorities when they contribute public funds.
- *Barriers between public and private status.* Different statutes for industry personnel and public research civil servants make personnel mobility between the two very difficult; different accounting rules often make private money brought by industry into a joint project difficult to use after it has been transferred to a university and is, therefore, subject to public accounting regulations.
- *Intellectual property rights conflicts.* Such conflicts are not infrequent, because in public research joint ownership is generally considered the rule for patents generated in cooperation with industry, whereas most MNCs consider joint ownership too constraining or at least bothersome. SMEs, which are generally more focused and have closer ties with a laboratory, particularly in the case of start-ups coming from the laboratory, are much more open to joint ownership.
- *Confidentiality issues.* French MNCs are often reluctant to involve public researchers in any research that is key for their strategy. (SMEs have less choice, because they are much more dependent on the public laboratory research.) The problem is particularly acute in European common research programs. Many enterprises stay away from projects that are too strategic for them.

As for the governance of public research, the influence of industry is in some cases even weaker than that of education. It is nil for most universities, which, as discussed previously, rarely have a research strategy in the first place. It is close to nil for some public research organizations, like CNRS, which have but a few representatives from industry on their board of directors and even fewer on their various visiting committees. But some public applied research organizations—for example, INRA for food and agriculture or CNES for aerospace—do take into account industry needs in their strategy. Indeed, some laboratories within those organizations are close to operating like an industrial research laboratory, performing research that is relevant for the industry. Examples of such industry-driven research also exist in some top universities—for example, Grenoble for electrical engineering, Strasbourg for biotechnologies, and Toulouse for aerospace. Last but not least, the same *grandes écoles* in whose governance industry plays an important role also tailor their research programs to fit industry needs. Such a strategy helps both the school in finding industrial funds and its graduates in finding industrial jobs.

In sum, despite the efforts and the tools that were put in place in the past two decades, meaningful and efficient cooperation between university and industry in knowledge production is limited to a few institutions—some applied research public organizations, a few universities, and a few *grandes écoles*—and involves mostly MNCs and a few high-tech SMEs. The situation is no better in knowledge sharing.

Knowledge Sharing

Knowledge sharing occupies the junction between knowledge-producing universities and innovation-producing industries. It is the key step in innovation: assembling elements of existing knowledge to generate a new product or a new process. It also is unanimously recognized as the weak point of the French R&D system: France is better at research than at using its research results for its industry. Indeed, unlike in other European countries such as Finland or Germany, where institutions like Tekes or Fraunhofer help fuel industrial innovation with academic research across the board, only a few enterprises and a few research institutions in France have succeeded in establishing cooperation all the way down to, say, laboratory-level prototyping. Some of those successes can be encountered with start-up SMEs directly issued from academic laboratories, and some are based on long-term relationships between MNCs and universities or research organizations, but successes are scarce, sporadic, and hardly systematic. This scarcity is caused by the above-noted difficulties that university-industry research cooperation encounters in France and by an additional difficulty that originates in the evaluation system, both for individual researchers and for research units, in university and public research organizations.

French researchers' career, salary, and advancement take into account almost solely their performance in knowledge production—that is, publications—and very little their performance in knowledge transmission, such as teaching for university professors, let alone their performance in knowledge sharing for the purpose of innovation. Indeed, in universities and in basic research organizations like CNRS, investing in such activity can be counterproductive for an individual's career, because working on applied research projects with industry hinders publication of scientific papers, which is the basis for promotion. Furthermore, applied research is often considered, not unjustifiably, as more risky than "pure" basic research: if an experiment does not work, it is nevertheless a subject for publication, though perhaps not in a top journal, but if a prototype does not meet expected specifications, all the efforts and time put into it are lost. Some recent changes in French legislation have softened the restrictions on civil service researchers' obtaining additional income from private activities, including advising or collaborating with industry, but even the current legislation maintains a ceiling on the extra private income authorized, which seriously limits the motivation. This limitation is waived for the inventors' share of revenues coming from royalties paid by industry, but only a handful of individuals benefit significantly from this facility. MNCs and SMEs try to take advantage of all possible ways and means to financially reward public researchers cooperating on their innovation projects.

One of those methods is to finance not the individual, but rather his or her laboratory. No limitation exists on the amount of support that a public laboratory can receive from an enterprise, and MNCs always find it profitable to subcontract applied research projects to academic laboratories, which usually charge only marginal costs, most of the operating expenses (salaries, office space, fluids) being already fully supported by the public budget. The only limits are the laboratory's human resources and the risk that, if the laboratory makes too much money with industrial contracts, the university will cut its subsidies accordingly, and the laboratory evaluation will be downgraded, because the laboratory's not doing enough basic research. Nevertheless, some very good laboratories in universities or *grandes écoles* achieve both top scientific ratings and high revenues from industrial contracts, plus maintain permanent relations with their customer MNCs. From the enterprise's perspective, the strategy of basing cooperation with any public research laboratory solely on its cheapness is short-sighted, but the majority of MNCs and SMEs—at least the best managed—are more selective, pick the best laboratories in their domain, and strive to build long-term trust and loyalty between them.

The New Programmatic Law for Research

The French public authorities are worried about the lack of efficiency of the country's research and innovation system. They have already designed legislation to improve the situation, as noted above. More recently, approved legislation, including the new programmatic law for research (*Loi de programme sur la recherche*), brings several important structural and institutional changes aimed at some of the current problems:

- The creation of academic trusts supporting universities, *grandes écoles*, and research organizations is made easier and their funding more attractive with generous tax credits for the donors, individuals, or corporations.
- The designation of Competitiveness Clusters (*Pôles de Compétitivité*) aims at pulling together all local resources (university, industry, local government) in a given scientific and technical domain to reach a critical mass and initiate a positive chain reaction.
- The newly created National Research Agency (Agence Nationale de la Recherche, or ANR) will encourage universities and *grandes écoles* to develop their own research strategy independently of the big national research organizations by funding research projects selected after calls for proposals.
- Another new agency, the Industrial Innovation Agency (Agence de l'Innovation Industrielle, or AII) will be given a mission parallel to that of ANR, the latter addressing knowledge production and the former addressing applied R&D. The AII modus operandi is not fully defined yet, but one hopes that it will boost innovation capabilities of the French R&D system at both its industrial and academic ends.
- A special type of federation of public and industry research centers, the Carnot institutes (Instituts Carnot), has been introduced to foster cooperative R&D projects. Several Carnot institutes will be designated, and the funds they will get from industry will receive matching grants from the public budget (à la Fraunhofer).
- Broader legislation (the Organic Budget Act, or *Loi organique de loi de finances*) affecting all public expenses states that each public expense should pertain to a program with specific objectives and achievement

> indicators. Public research funding is no exception, and starting with fiscal year 2006, every public research entity should have several quantitative objectives regarding not only knowledge production, but also applied research and knowledge transmission. Needless to say, this emphasis is a double revolution for French research: first, to be assigned quantitative objectives and second, to get objectives pertaining not only to basic research (in effect, publications), but also to innovation.

The programmatic law for research, the Organic Budget Act, and other recent legislative steps will introduce major changes in French public research. MNCs and SMEs have, in general, received those legislative innovations well. Those companies are now actively updating their R&D strategy to take advantage of the new facilities, even though those facilities often have the side effect of creating additional layers of complexity in the already-complicated French administrative system. But will these changes be enough? Unfortunately, there are reasons to believe that the answer is "no," mainly because the present reforms stop short of lowering the barriers that exist between public and industry research as well as between public and industry researchers. In the new global economy, the French model of a state-controlled academic system, in which all universities and all faculties are deemed equal, cannot reasonably be expected to remain competitive. National comparisons within France already show that private *grandes écoles*, or public research institutions where private industry plays an important role, are more effective and more reactive than the ones that depend solely on the state. International comparison studies should confirm that countries that introduce autonomy, competition, and accountability into their academic system (a) open public research and universities to private funding and governance and (b) gain efficiency and competitiveness for their industry and their economy.

CHAPTER 17

Specific Approaches to University-Industry Links of Selected Companies in Thailand and Their Relative Effectiveness

Peter Brimble

For middle-income countries in East Asia, developing innovation capability is an essential part of the strategy to sustain the high growth rates that they have enjoyed in the past. Thailand is no exception. Although after the 1997 financial crisis Thailand resumed its growth, much of the growth has come from rising export prices, public investments, and domestic consumption demand, not improvements in competitiveness and productivity. These factors will remain important. However, a strong growth performance will still need to be buttressed by a robust expansion of exports.

Much of the material in this chapter is drawn from the joint research and work carried out by the author and Professor Rick Doner. See Brimble and Doner (forthcoming) and references cited therein. The chapter, however, has been prepared and compiled solely by the author.

Global competition is intensifying, especially with the emergence and integration of China into the global market. Faced with this increased competition, multinational corporations (MNCs) are gearing up to improve and differentiate their products from each other while cutting costs. Such a move affects firms in Thailand, because many of them are part of the global production networks supplying these MNCs and buyers in industrial countries. Thai firms need to respond to the increasing pressure to cut costs while meeting tougher requirements. The ability of Thai firms to do so will depend on their innovative capabilities, which university-industry links (UILs) could augment.

In this chapter, six case studies illustrate the current state of UILs in Thailand. These studies highlight both the efforts of a few private firms (including MNCs) to create links and the weak response from universities and government agencies. The chapter identifies factors contributing to the deficiencies in current arrangements and suggests future policy directions.

Six Case Studies of UILs in Thailand (plus IDEMA)

The following cases will be examined in some detail and then the key lessons will be derived.

- Seagate Technology
- KR Precision (KRP; now Magnecomp)
- IDEMA Thailand
- Toyota Technical Center
- AAPICO
- Mitr Phol Sugarcane Research Center Co.

Seagate Technology

The major UIL success story in electronics has resulted from numerous initiatives of Seagate Technology since the early 1980s. Largely on its own, Seagate has undertaken a number of successful, long-term link initiatives, most of which have enjoyed solid university support. On the training side, Seagate put together a loose consortium of five universities to provide a range of customized courses and produce engineers capable of handling the management and automation of Seagate's high-technology production facilities. The universities provide the facilities and most of the teaching resources, while Seagate provides assistance with curriculum development and selected trainers. Seagate has put large numbers of engineers through this program with considerable success. Another training initiative involved active participation in the government's cooperative training program. University graduates participating in this program spend a period of time in businesses as a part of their course requirements. Taking about 20 to 40 students per year, many from nearby Suranaree University of Technology (in northeast Thailand), Seagate has become a much-respected host that takes great care in preparing projects and activities for the students—something that reportedly benefits both sides greatly.

Seagate stands alone in Thailand in building long-term relationships with universities in the research and development (R&D) field. Several years ago, working with a young, U.K.-trained professor on magnetic recording, Seagate established a joint R&D center with Khon Kaen University (also in northeast Thailand). This R&D center emerged from Seagate's prior work with the professor. And in late 2004, following the Khon Kaen model but without the strong personal link, Seagate and Suranaree University of Technology opened the second magnetic-head technology R&D center. Seagate reports satisfaction with both R&D centers, which have published advanced papers, supplied quality recruits, and assisted with problem solving. However, no public official or representative from another university has approached Seagate about its experience with the two R&D centers or about the possibility of expanding this model with support from the public sector.

KR Precision

KRP was one of the few Thai firms that was active in the Thai hard disk drive industry and was listed on the Thai stock market. It was active in the very competitive suspension arm sector and has now been taken over by Magnecomp. The new firm focuses more on lean manufacturing through investment in retooling certain kinds of operations and less on general strategy. Very likely this change will lead to greater vertical integration with little likelihood of any UILs materializing.

KRP itself, driven largely by the need to compete, had undertaken a number of activities both inside and outside Thailand to develop design capability for tooling—critical for its segment of the industry. Within Thailand, KRP had developed several close relationships with professors in selected areas (indeed, the highly proactive chief technology adviser was hired away from Chulalongkorn University after one such activity) but had not found the institutional capacity to build stronger links with any particular university. KRP preferred hiring at the individual level, because the benefits of a formal relation were not worth the time and bureaucracy. Moreover, Chulalongkorn University has yet to develop the organizational infrastructure to support formal UILs.

However, KRP was one of the few firms in Thailand that had worked intensively with several outside agencies to do various technology tasks:

- KRP worked with the Disk Storage Institute in Singapore to prepare a circuit design for a new technology product. KRP now has the design capacity, which gives it a lead over its competitors.
- KRP worked with a world expert in laser bending and his student at Purdue University to achieve cost-effective outcomes.
- By networking with the Industrial Technology Research Institute (ITRI) in Taiwan (China), KRP was able to build up capacity in microchip memory systems. But KRP discovered that a partnership with ITRI came with strings. For example, ITRI's rules required it to develop a prototype but then transfer the blueprints to a firm in Taiwan, China, for mass production of the final product there. Also, ITRI was prepared to contribute little to the cost of the project.

In short, KRP's experience was that finding resources or institutions to support UILs in Thailand was difficult, and the firm had to look overseas for assistance with technology development.

IDEMA Thailand

An interesting collective initiative involves coordination among members of the Thai branch of the global hard disk drive (HDD) industry association (the International Disk Drive Equipment and Materials Association, or IDEMA), the Asian Institute of Technology (AIT), and several disk drive producers. Begun in 1999, the initiative first attempted, with only moderate success, to develop a Certificate of Competence in Storage Technology Program at AIT, a program similar to one implemented by IDEMA in Singapore. Then in 2003, the National Science and Technology Development Agency (NSTDA) financed the preparation of an HDD industry cluster study to generate industry consensus on projects beneficial to the HDD cluster.

The commencement of the cluster study marked a major change in the government's approach to the HDD industry. As the research proceeded, the minister of industry pressed for reforms to support the growth of the HDD sector, and the Board of Investment issued a statement giving the industry priority and subsequently announced a special incentive package for the industry. Then NSTDA identified the HDD industry as the focus of its pioneer cluster development project, which included several cluster-strengthening components, such as improving engineering training, defining common operational problems, and developing visual inspection software. Several of those initiatives build on prior initiatives by Seagate, and most are designed with explicit attention to the development of academia-industry consortia involving institutions such as AIT and King Mongkut's University of Technology in Thonburi. Considerable progress has been made in implementing the rich range of projects that will all serve to strengthen the industry.

Key lessons can be drawn from the HDD industry's mixed experiences with UILs. First, university resources—institutional, financial, and technical—and, at a minimum, receptivity, are prerequisites to successful link development. Second, collective industry efforts are generally required; although large and heavily committed firms such as Seagate can, in isolated cases, make progress on their own, even they recognize the eventual limitations of a lone approach. Third, government recognition of the industry's importance and of the collective nature of its upgrading requirements is key to ongoing UILs. Yet precisely the weaknesses in these and other areas of Thailand's national innovation system have impeded the emergence of links among firms, universities, and research entities.

Toyota Technical Center

In 2003, Toyota established the Toyota Technical Center–Asia-Pacific (TTCAP) to operate as an R&D base for Toyota's global operations in offering product designs and modifications to suit requirements in the region and to provide testing and evaluation services. TTCAP is effectively 100 percent owned by Toyota Motors Corporation from Japan. TTCAP provides regional engineering services with the following objectives: (a) develop best practices for Asia-Pacific demands; (b) contribute R&D supporting Toyota's global strategy; and (c) possibly collaborate with companies in Australia, as well as conduct research for firms in the Association of Southeast Asian Nations region plus India. TTCAP located in Thailand because of its (a) good infrastructure, (b) political stability, (c) attractive geographic location, (d) potential for a good human resources base, (e) strong automotive parts base, and (f) good support from the Board of Investment. The potential for links with the local Toyota operation appeared to be a minor consideration. Toyota's decision to locate the facility in Thailand evidently also had little to do with local technical institutions.

TTCAP is essentially a self-contained operation with only one technical agreement—that with Toyota headquarters in Japan. It takes orders from Japan and sends results and outputs back to Japan (possibly collaborating with the center in Japan but probably not much). TTCAP has very basic training links with NSTDA—nothing to do with R&D or TTCAP's core business activities—and has no plans for any deeper links with the universities beyond simple networking to recruit employees.

TTCAP's almost complete lack of any integration into the local economy reflects the state of Thailand's technology capability, but its presence also points to Toyota's views regarding longer-term potential. TTCAP's managers who were interviewed are interested in exploring local links if that option appears sensible, and those links could emerge if Thai universities and researchers take the initiative.

AAPICO

AAPICO is an innovative automotive parts operation that produces dies and jigs for the main assemblers both in Thailand and for export. In recent years, as the technical demands of the industry have grown and the resources of the company have expanded—partly through a listing on the Thai stock market—AAPICO has started a number of promising programs with universities.

The company is providing scholarships for engineering students in Thammasat and has been pushing for an elective bachelor's-level course for engineers at Thammasat. This course would be based on AAPICO's experience and give students a sense of what is involved in the evolution of a firm through plant visits and lectures by AAPICO staff members. So far, the universities are not forthcoming, because assisting industry has low priority. While continuing to pursue this project, AAPICO is attempting to meet its growing demand for better-trained workers by starting an AAPICO high-tech training school. The school would be a collective effort in that it could also train people from other firms.

The AAPICO experience further underscores the lack of interest in UILs among universities and public agencies. Even major government initiatives such as the recent Mold and Die Program launched by the Ministry of Industry have made no contact with AAPICO.

Mitr Phol Sugarcane Research Center Co.

Mitr Phol, one of the largest sugar millers, established an in-house R&D center in northeast Thailand in 2000 on the heels of abortive efforts by the government to set up similar facilities. The long-term viability of this effort is still unclear, but its very establishment raises questions about why an individual firm would undertake such an effort if the risks of failure are high: why internalize the costs of such research when the benefits of success—improved cane varieties—could easily leak out to competitors? An important part of the answer relates to the limits of technology spillovers: each cane variety is somewhat specific to soil and climate conditions. Furthermore, the very process of developing and testing the new cane varieties allows Mitr Phol to strengthen its links with growers and thus ensure a more reliable supply of high-quality sugar. Finally, a new variety can help build Mitr Phol's overall reputation and image, an important goal of the firm's current chief executive officer.

This firm-specific effort involves some use and promotion of UILs. Mitr Phol is now working with NSTDA to streamline the process by which firms get tax deductions for R&D work. The firm is also cooperating with another public technology institution under NSTDA, MTEC, to develop improved equipment. The effort holds the potential for links with universities. Although such links are at present minimal, the center hopes to establish ties with nearby Khon Kaen University, after failing to develop stronger links with the more obvious candidate, Kasetsart University. Again, a private firm has been ready to take the initiative, but in the absence of a response from other parties involved in creating UILs, the networks that would build technology are not yet materializing.

Lessons Learned and Best Practices

Most firms operating in Thailand generally have not exhibited strong interest in UILs. A (small) number of companies, however, have been very active in building technological capability and seeking links with universities, but so far most have either done things in-house or through informal connections. Many initiatives have started out with big ideals and objectives and have then gone nowhere or are proceeding at an unimpressive pace. This result partly reflects the fact that Thailand's current strategy of combining protection in the domestic market with exports of natural resources and of low-wage manufactured goods discourages Thai-based firms from aggressively attempting to raise technological levels and create UILs. Firms such as Toyota that operate in mid- and high-technology areas and that are able to draw on R&D from outside the country or to pursue such activities in-house are less affected by government policy.

Another factor inhibiting private sector activity is the relative lack of cohesion within and among sectors. Relatively few encompassing associations are able to reconcile, for example, the interests of sugar millers and growers, or of spinners, weavers, dyers, and garment producers. Furthermore, associational activity has traditionally focused on lobbying for specific policies and protection rather than promoting collective goods devoted to improving efficiency and technology. Productivity-oriented associational activities tend to occur largely where local firms are under competitive pressure and where political leaders see the fate of the industry as strategic, as has been the case for both Thai rice and garments. In other words, as demonstrated by cross-national research, private sector collective action typically requires public sector support, which has been forthcoming in only a few instances.

Under those conditions, up-to-now effective Thai UILs not surprisingly have been those undertaken by large firms—large garment exporters, Seagate in hard disk drives, and the CP Group in shrimp. Furthermore, the vulnerability of the shrimp industry, combined with its tremendous foreign exchange earning capacity, the weakening competitiveness of shrimp farmers, and the CP Group's political leverage, have meant that such links are the strongest in the shrimp industry. When and if sugar is exposed to similarly dire threats, large sugar millers will also likely become more proactive, although much will depend on the responsiveness of the universities as well. (One may also begin to see such efforts as sugar millers seek alternative uses for cane—for example, energy cogeneration, paper, and ethanol.)

Indicators of Effectiveness of UILs

The key reasons that UILs in Thailand do (or do not) succeed or reach their full potential appear to be the following:

- First, the move toward UILs must be backed up by the full commitment and involvement of top management and representatives from all the stakeholders: the roles for industry, universities, and government must be clearly defined. The ambiguity and lack of clarity on the part of Thai government remains a major stumbling block. Creating UILs is as much a political challenge as a technical and organizational one.
- Second, the persons assigned to manage the link programs, either in universities or the public sector, must have some experience with industry as well as a flair for dealing with the private sector. Experience with the research technology organizations under NSTDA as well as King Mongkut's University of Technology in Thonburi highlights this success factor.

- Third, link programs must be based on entrepreneurial foundations, both of university staff members and of private industry representatives, with a well-thought-out development plan. In addition, from the university side, the programs should relate to the core functions and resources and ideally involve elements of more than one activity—for example, research with training, training with consulting, or all three activities. The Seagate research institutes at Suranaree University of Technology and Khon Kaen University embody those factors.
- Last is the important issue of trust. Universities and industries have different time frames, different cultures, and different motivations. Their understanding of knowledge, the knowledge-generation process, and the knowledge-use process differs greatly. The challenge is to bridge the gap—to enhance the common understanding of what each side has, what each side wants, and what each side needs. Link programs, therefore, should focus on building both credibility with the private sector and acceptance from universities.

Reference

Brimble, Peter, and Richard F. Doner. Forthcoming. "University-Industry Linkages and Economic Development: The Case of Thailand." *World Development*.

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Note: f, t, and n indicate figures, tables, and notes, respectively.

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