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Cultivating Research Universities and Industrial Linkages in China: The Case of Shanghai

WEIPING WU *
Virginia Commonwealth University, Richmond, VA, USA

Summary. — Evidence in industrialized countries shows that universities can supply the crucial underpinnings of dynamic industrial clusters within metropolitan regions. A key component of China's recent reforms in the national innovation system is the promotion of university-based research and technology transfer. The primary purpose of this paper is to examine the interactions between two elite universities in Shanghai (Fudan University and Shanghai Jiaotong University) and the metropolitan economy. In particular, it analyzes major institutional changes within the universities and policy changes at local and national levels that have allowed more business engagement. As the universities gain greater autonomy, they are adopting distinctive approaches to commercializing academic research and managing industrial linkages.

Key words — innovation diffusion, university–industry linkage, higher education reform, urban economy, Asia, China

0. INTRODUCTION

Research, mainly on industrialized countries, indicates that research-oriented universities can assist firms directly through a variety of linkages and the provision of skills and indirectly by way of spillovers. These universities contribute to national development, and there are also a number of notable instances where universities have supplied the crucial underpinnings of dynamic industrial clusters within metropolitan regions (Abdullateef, 2000; Appleseed, 2003; Mayer, 2003; Wu, 2005).

In the past two decades, strategies for enhancing research and innovation capabilities have come to occupy a more important position in China's development policy as the country moves to catch up with the west. A series of ambitious initiatives have been launched to enhance its technological capabilities and reform its national innovation system, including several national programs and policies that directly affect university research and funding. 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. In addition to technology transfer through licensing and other arrangements, universities are encouraged to set up their own technology enterprises, become partners in joint high-tech ventures, or invest in high-tech enterprises (Zhang, 2003).

Long the leading production center and often seen as China's economic locomotive, Shanghai was the city where China's first modern institutions of higher learning were established. During the socialist era, Shanghai's research institutes and laboratories were the ones entrusted with the task of advancing China's military and industrial technology. Today, following the national lead, Shanghai has been implementing a set of strategies to build a municipal innovation system. Spearheading this effort are two of the top ranked and oldest universities in China and the best in Shanghai. They are Fudan University and Shanghai Jiaotong University (SJTU), both of which are moving aggressively to strengthen their research-orientation. With joint funding from the Ministry of Education (MOE) and the Shanghai Municipal Government, they have expanded the range of academic disciplines and have invested substantially in research as well as in-campus construction. Both have

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augmented the institutional support to promote the commercialization of research and are encouraging spin-offs and startups drawing on faculty research.

The purpose of this paper is to examine the economic contribution made by the two universities in Shanghai and analyze the effectiveness of their interactions with the metropolitan economy and beyond. The paper will characterize 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 these universities themselves have promoted the growth of collaborative local and international networks to encourage ties between business and research. The paper also will analyze key institutional changes within the universities and policy changes at local and national levels that have stimulated engagement with the local economy. In addition, the paper will address the impact of universities' engagement with the business community on the academic tradition.

The paper first provides a brief overview of the related literature on the relationship between universities and national innovation system, and the institutional underpinnings of effective university–industry linkages. Section 2 outlines how recent changes in China's national innovation system have affected Shanghai and the two universities, and examines key research and development (R&D) policies and initiatives proposed and implemented in Shanghai. In Section 3, the paper characterizes the disciplinary span of research and major educational reforms in Fudan and SJTU. Lastly, the paper explores the mechanisms through which the two universities cultivate linkages with the metropolitan economy and beyond.

1. UNIVERSITY–INDUSTRY LINKAGES IN THE CONTEXT OF NATIONAL INNOVATION SYSTEM

Three key institutional actors—industry, research organizations, and government—occupy important positions in all national innovation systems (Fujita & Hill, 2004; Mowery & Rosenberg, 1993). As a complex network of agents, policies and institutions supporting the process of technical advance and spanning all industries, national innovation system varies across major industrialized countries (Crow & Bozeman, 1998; Nelson & Rosenberg, 1993; Porter & Stern, 2001). In terms of the relative importance of universities, the United States, continental Europe (perhaps with the exception of Germany), and Japan offer three distinct models. A major feature in the postwar US national innovation system is the immense expansion of research in institutions of higher learning. By simultaneously providing funds for university research and education, the federal government has strengthened the university commitment to research (Mowery & Rosenberg, 1993). The passage of the Stevenson–Wydler Technology Innovation Act and the Bayh–Dole University and Small Business Patent Act (both in 1980) has ushered in a new era in the transfer of publicly funded intellectual property (IP) to industrial firms (Feldman & Francis, 2003). These and other institutional changes have allowed enterprising individuals to license technology out of their own labs to create startup companies and encouraged universities to embrace closer interactions with industry to facilitate innovation diffusion. As a result, 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.[1] There are diverse interfaces between research universities and the industrial sector, particularly in the biotech, microelectronics, and computer industries (Mowery & Rosenberg, 1993).

Industry-university relations in continental Europe, on the other hand, have encountered legal prohibitions against faculty collaboration with commercial firms in some countries and cultural biases against academic involvement with commerce in others. Earlier, this academic culture did not encourage direct involvement with industry, and tended to emphasize fundamental research. Since the late 1980s, however, attention has shifted to technology policy supporting commercialization and academic technology transfer. Programs developed following the Single European Act of 1987 encourage matches between universities and firms, placing particular emphasis on the quick delivery of tangible commercial results (Owen-Smith *et al.*, 2002; Poyago-Theotoky, Beath, & Siegel, 2002). The Japanese model illustrates yet another alternative as large industrial firms tend to integrate the process of innovation—from basic or product research to commercialization—within one organizational framework (Fujita & Hill, 2004). Thus private firms are the core actors in the national innovation system. Prior to the mid-1990s, universities mainly focused on training students for corporate and government employment and engaged in informal research collaboration with firms. But an extended economic recession and concerns about reduced competitiveness in key industries have induced policymakers to pin more of their hope on scientific research as a means of achieving economic revitalization. The national government enacted the Basic Law on Science and Technology in 1995, and instituted reforms to facilitate university–industry linkages. [2] Currently there is a shift toward university research, especially longer term research with potential commercial implications (Etzkowitz, Webster, Gebhardt, & Cantisano Terra, 2000; Kodama, 2005). Yet localized spillovers are infrequent and there are very few examples of university associated clusters.

This shift toward broader university–industry linkages in continental Europe and Japan is in line with what some scholars have termed as an emerging trend toward the entrepreneurial university (Etzkowitz *et al.*, 2000). Within the context of today's knowledge-based innovation, the model of the university center as a vehicle for technology transfer has become more important, acting as a conduit through which knowledge exchange and exploitation is made more effective. At their most effective, universities also can serve as nodes in regional or global systems linked to other major centers of learning across the world, contributing to the sparking and diffusion of ideas.

There are several ways through which linkages between universities and the business community can be developed. A popular mechanism is when a firm contracts with a university researcher to conduct R&D for the firm (principle-agent relationship). At the other extreme is the case when a university researcher develops an idea for commercialization and enters into a contract with a firm, often through a spin-off company of the university. An intermediate mechanism occurs when the university helps the firm improve its understanding of the underlying basic science and the firm develops the product or technology. Another type of intermediate link is through joint collaboration between a firm and university to develop a product or technology (Poyago-Theotoky *et al.*, 2002). These university–industry linkages can take a variety of forms, ranging from formal contractual relationships managed through university technology transfer offices (e.g., licensing) to more informal arrangement such as educational partnership and consultancy. The licensing of technologies to firms is perhaps the most direct way in which academic research can be translated into industrial growth.

Research shows that, within the university, there are important institutional underpinnings for building commercial linkages. The primary source of growth in university licensing stems from an entrepreneurial bent of university administration rather than a change in faculty research (Thursby & Thursby, 2004). University administration can influence the incentives of the technology transfer office and faculty member by establishing university-wide policies for sharing licensing income. Evidence from the United States indicates that it is the shift in the licensing behavior of universities that is responsible for the surge in licensing activities (Poyago-Theotoky *et al.*, 2002; Thursby & Thursby, 2004). The existence of a formal relationship with a science park enables a university to generate more patents and also allows them to more easily place Ph.D. students and hire preeminent scholars (Link, Scott, & Siegel, 2003). The majority of university inventions are so embryonic that successful commercialization depends critically on faculty participation in further development. Faculty involvement needs to go well beyond simply disclosing research, with faculty often identifying licensees as well as working with licensees in further development (Jensen & Thursby, 2001; Thursby & Thursby, 2004).

Under China's recent reforms, university–industry linkages are built through two broad categories of mechanism. The first is technology transfer through licensing and other arrangements such as consulting, joint or contract R&D, and technical services. This resembles how universities in the West build industry linkages. The second mechanism, which is almost uniquely Chinese, is through university enterprises (broadly defined) that are invested in and owned wholly by universities, operated and owned jointly with other entities, or invested in partially by universities (Ma, 2004; Zhang, 2003). In 2001, the State Economic and Trade Commission and 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] More importantly, MOE came out with a clear directive in 2002 that would encourage the development of university enterprises, after some heated debates on whether commercialization and industry linkages are a central mission of universities. Now research and technological innovations are seen, at least from MOE's point of view, as a key mechanism through which universities contribute to national and local economies (*Chinese University Technology Transfer*, October 2002, p. 10).[4] In addition to commercialization, enterprises are seen as a way to provide supplemental funding for university operation and absorb surplus personnel on campus as public universities are not allowed to lay them off (Zhang, 2003).

Through these reform measures, universities in China have increasingly assumed commercial roles and are important players in many science parks. Top university professors, in particular, are finding commercial applications for their research projects. The local impact of university-based innovation and entrepreneurship, however, should not be overstated. In 2001, only about 40% of university enterprises were involved in science and technology (S&T) related activities (Ma, 2004). Their sales revenue made up a mere 2.3% of all high-tech enterprises nationwide, while nearly half of such revenue was contributed by enterprises affiliated with Beijing and Qinghua Universities (China's top two institutions). The national estimate is that only about 10% of university research and innovation has been put to any kind of commercial use (*Science & Technology Industry of China*, March 2000, p. 52). This is not surprising giving that the history of university–industry linkages is still short in China. But in some ways it echoes the trends in other parts of the world where large firms rather than universities have initially taken the lead in promoting technological innovation and creating a skilled and entrepreneurial work force that is contributing to the agglomeration economies and cluster development in some metropolitan regions (Mayer, 2003). Part of the difference may be attributed to the cultural predisposition held by some universities to contribute to knowledge for its own sake and their unwillingness to allow commercial interest to influence research (Feldman & Desrochers, 2004; Owen-Smith *et al.*, 2002). Yet another reason may be the lack of a supportive and innovative environment in the local community.[5]

2. A NASCENT LOCAL INNOVATION SYSTEM IN CHINA'S CHANGING NATIONAL CONTEXT

Since 1979, China's national innovation system has been undergoing drastic reforms. Perhaps one of the most significant measures is the dismantling of the Soviet model of functionally specialized organizations whose activities and interactions would be managed by central authorities. Under this model, research, including all innovative activities, was conducted by research institutes, channeled to state-owned enterprises for production, and distributed by state-owned distributors. A multitude of central ministries coordinated these units, creating a vertically rather than horizontally integrated system dependent on centralized, top-down allocations for necessary inputs. The main administrative body was the State Science and Technology Commission (later renamed as Ministry of Science and Technology or MOST).[6] Since the early 1980s, the central government has been decentralizing responsibility and the necessary authority to make decisions parallel to new levels of responsibility has moved down. This is accompanied by measures to encourage a closer relationship between research and production through horizontal, market-based ties between research institutes/universities and enterprises (Gu, 2003; Liu & White, 2000; Suttmeier & Cao, 1999).

A new legal framework has been put in place at the national level to enable such ties. In April 1999, the State Council gave its approval to the "Several Provisions on Promoting the Transformation of Scientific and Technological Achievements." The "Provisions" make relatively generous allowance for rewarding the discoverers of new, commercially useful knowledge and make it easier for research personnel to move back and forth between research and business (Suttmeier & Cao, 1999). The central government also has paid more attention to IP protection, creating the Chinese Patent Office in 1980 and enacting its patent law in 1985 and copyright law in 1990 (Hu & Jefferson, 2004; Liu & White, 2000; Suttmeier & Cao, 1999). The patent law was substantially revised in 1992 with expanded scope for patent protection, leading to a sharp rise in the number of patents granted.

Following national directives, concerted efforts to establish a municipal innovation system began in Shanghai in the 1990s with targeted policies to nurture R&D institutions, increase investment in R&D, build a support infrastructure to facilitate research commercialization, develop an adequate regulatory and legal framework, and invest in human capital (Fan, 2003). Municipal authorities hoped that by

2005 a basic innovation system would take shape and enable Shanghai to remain at the forefront of national R&D. [7] To implement national laws, similar local laws have been enacted governing commercialization of high-tech innovations and IP protection. In addition, a network of service centers has been established to facilitate the commercialization of product or process innovations. Chief among them are a technology exchange center, a high-tech commercialization service center, an S&T consulting service, and several high-tech enterprise incubators (Fan, 2003). Municipal authorities also have relaxed restrictions on enterprises in hiring personnel with college or graduate education from other parts of China and from overseas by allowing them larger quotas for urban household registration.

Accompanying efforts to encourage research commercialization and horizontal linkages, a major shift has occurred in the national distribution of R&D effort among the three major sectors performing R&D—government R&D institutions, the enterprise sector, and universities. Whereas industrial enterprises performed less than 40% of the country's R&D as recently as mid-1990s, they now perform more than 60%. By 1999, over half of China's scientists and engineers worked in enterprises, representing a considerable change from the early 1990s when state institutes employed most R&D workers. The change also reflects steps taken to send older staff into retirement, as well as moves to eliminate some state-owned R&D institutes by merging them into existing industrial enterprises or university R&D enterprises, or by disbanding them altogether (Hsiung, 2002; Hu & Jefferson, 2004). Research institutes are encouraged to launch commercial spin-offs based on successful applied research in their laboratories. There are now a variety of spin-off R&D enterprises—some state-owned, some collectively-owned, and others privately-owned, and they have become a lucrative and increasingly important source of revenue for many research institutes.

Actions in Shanghai mirror the national trends. Municipal authorities have particularly encouraged the development of private technology enterprises through a broad array of incentives in financing, taxation, IP protection, commercialization, and support services since the early 1990s (Fan, 2003). As a result, such enterprises have mushroomed, now counting for the bulk of city's scientists and engineers (see Table 1). The rise in the number of patents, particularly those registered by industrial enterprises, also is rapid. Most of these private enterprises are in electronics, information technology (IT), software, communications, and biotech industries. They tend to adopt more flexible measures to turn research findings into new products. After actively pursuing high-tech investment, Shanghai also is home to dozens of R&D centers of multinational corporations (MNCs)—in such industries as automobiles, machinery, biotechnology, pharmaceuticals, and software. Although some R&D activities are not cutting-edge and involve adaptations to suit local markets, MNCs are clearly taking advantage of Shanghai's skilled labor force, quality university labs, and local production clusters (Chen, 2004; Xue & Wang, 2000).

The mushrooming of private technology enterprises also has contributed to a rising level of R&D expenditure in Shanghai, as they tend to invest more in R&D (averaging 5–10% of corporate investment) than other types of enterprises (Fan, 2003). As a whole, R&D investment in the city has increased significantly, reaching over 12.9 billion YMB in 2003. This was equivalent to 2.06% of the municipal GDP (see Table 1), a level much higher than the rising national average (about 1.01 in 2000). [8] Closely following the national trend,

Table 1. *Selected R&D statistics in Shanghai, 1990–2003*

	1990	1995	2000	2003
Expenditure in R&D as % of GDP	1.36	1.32	1.69	2.06
Total number of patents	924	1,436	4,048	16,671
Patents by industrial enterprises	156	233	2,099	13,654
Patents by research institutions	145	77	215	523
Patents by universities	81	49	183	466
Number of private technological enterprises (PTE)	–	6,787	12,316	21,516
Scientists and engineers in PTE (1,000 persons)	–	59.8	89.0	117.7

Source: Shanghai Statistical Bureau, *Statistical Yearbook of Shanghai, 2004*. Beijing: China Statistics Press, 2004.

Shanghai's R&D expenditure is concentrated in product or process development (70%) while basic research constitutes about 7% and applied research about 23% (Fan, 2003). To encourage more basic research, the Shanghai Science and Technology Commission (STC) has launched a series of high-profile grant programs. The peer-reviewed grants favor young scientists and those with well-established research teams. The programs are also intended to help Shanghai scientists compete on a national level, although it promises adequate levels of funding for only a core group of scientists performing vital but unprofitable basic research (*Science*, August 12, 1994).

Several of the major national S&T programs launched since the mid-1980s have left an imprint on the city. In particular, the designation of high-tech/science parks in Shanghai followed the launching of the national "863" and "Torch" programs, to promote the development of high-tech industries (Shanghai Municipal Government, 2004).[9] Science parks are used as incubators for cultivating such enterprises and promoting research spin-offs—including Caohejing High-Tech Park, Zhangjiang Science Park, Jinqiao Science Park, Shanghai University Science Parks, China International Textile Technology Development Zone and Jiading High-Tech Park. Specifically, the development of high-tech industry has been spearheaded by the Zhangjiang Science Park in the Pudong New Area. The park's two leading industries are IT and modern biotechnology and pharmaceuticals.[10]

The promotion of university-based research, which had been seriously neglected in the pre-reform period, is a national initiative spearheaded by MOE. Universities are yet to become key drivers of national R&D, although they are now a substantial player in two national S&T programs focused on basic research—"Climbing" and "863" (Hu & Jefferson, 2004). About a third of "863" projects are carried out by universities, so are close to two-thirds of projects funded by the National Science Foundation (*Science & Technology Industry of China*, March 2000, p. 52). But universities have consistently spent less than other R&D institutions, growing from 2.8 billion RMB to 6.4 billion RMB between 1995 and 2000, a little over 10% 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 2.76 billion RMB in 2003, a mere 1.2% of the city total (Shanghai Science & Technology Commission, 2004).[11]

The central government is now providing more funding to elite universities while encouraging joint funding from local governments and enterprises and allowing for the opening of privately-funded educational institutions (Hsiung, 2002; Ma, 2004; Suttmeier & Cao, 1999). An important initiative is "Project 211," which provides significant funding for construction on university campuses around China (Hsiung, 2002). Jointly sponsored by the State Planning Commission, Ministry of Finance, MOE, and provincial governments, this project targets a group of 211 institutions during the 9th Five-Year Plan period (1996–2000). Both Fudan and SJTU were recipients of "211" funding. On the heels of "Project 211," MOE launched another nationwide program "985" aimed to turn China's top universities into world-class research universities. Competition for "985" designation has been fierce as selected institutions would receive 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, in addition to Shanghai's Tongji University that was included only in the second phase.[12]

Broader university reforms also have been ongoing in curriculum development, faculty recruitment, and enrollment expansion. Various initiatives have been introduced to link schools run by different ministries, in order to avoid duplication of courses and teaching programs. Universities are also reforming their curricula, to eliminate certain topics now considered redundant, in order to make the curriculum more flexible, interdisciplinary, and relevant. A series of aggressive programs have been designed to attract talented returnees to China from institutions overseas and reward outstanding scientists, such as the "Hundred Talent Program" and the Cheung Kong ("Changjiang," or Yangtze River) Scholars Program. In addition, nationwide university enrollment has expanded significantly. For instance, annual enrollment for local students in Shanghai's higher education has seen steady increase—for universities from 19,000 in 1991–95 to 30,000 in 1996–2000 and for adult continuing education from 10,000 to 18,000, and for vocational schools from 22,000 to 35,000 (Shanghai Academy of Social Sciences, 1997).

Shanghai's efforts in building the local innovation system are paying dividends as it now scores higher than Beijing in nearly all aspects of innovation environment, according to a recent survey of high-tech manufacturing and knowledge-intensive service firms in the two cities (Wang & Tong, 2005). This is consistent with findings from research done by Jefferson and Zhong (2004). Using a composite index of R&D capabilities (including such indicators as international exposure, human capital resources, the R&D network, and the policy setting), they rank Shanghai above four other major Chinese cities (Beijing, Guangzhou, Chengdu, and Tianjin) along all dimensions. Shanghai's R&D capabilities are in fact close to those in Seoul, South Korea, and Shanghai has begun to create the institutional attributes that could boost the productivity of R&D. According to another study ranking 10 Chinese cities by the Management School of China Southeast University, Shanghai ranks first in aggregate competitiveness (cited in Jefferson & Zhong, 2004). It also ranks first in the competitiveness of capital, technology, location, social order, and management; and ranks second in the competitiveness of human capital.

3. BUILDING WORLD-CLASS RESEARCH UNIVERSITIES AT FUDAN AND SJTU

Selected as jointly managed universities between MOE and Shanghai Municipal Government, Fudan and SJTU have received strong government endorsement as well as substantial investment. Among the first group selected for "Project 211" and both phases of "985" Program, they have received the largest investment from the central and municipal governments in their histories.[13] "211" funding is slated for developing key disciplines, teaching and university facilities, and campus infrastructure. With this funding, for instance, a broadband network using fiber optics was established at Fudan University in 2001, the country's first fiber-optic broadband network on a university campus (*Alestron*, June 6, 2001). Funding from the "985" Program is targeted more at raising research capacity, widening disciplinary span and developing new interdisciplinary research programs, all ingredients considered necessary by MOE to build world-class research universities.

One of the first steps for both universities has been to assemble a more comprehensive range of academic programs. As Fudan's tradition favored humanities and sciences while SJTU was oriented more toward engineering, their approaches naturally differ (see Table 2). For Fudan, the expansion had been largely within the confines of humanities/sciences until the merger with the Shanghai Medical University on April 27, 2000. This allowed for the creation of a medical center with significant research strength and clinical capacity.[14] New programs in sciences include China's first School of Life Sciences (1986) integrating biophysics, biochemistry, ecology and genetics, and a School of Computer Software (2002) focusing on mobile computing and electronic commerce. Expansion in the humanities and social sciences is limited to reconfiguration of departments into new schools, some taking on a policy orientation such as the new School of Social Development and Public Policy (2004). Fudan has nonetheless made a small inroad into engineering, developing a new School of Information Science and Engineering (2000) and a Department of Environmental Science and Engineering (1996).

SJTU, on the other hand, has come through several stages of academic expansion since the 1980s (personal interview). Although a comprehensive university before the Cultural Revolution, its distinction has always been in such engineering fields as high-speed information network engineering, advanced mechanical manufacture technology, naval architecture and ocean engineering, power engineering and energy utilization, control theory and application of complex systems, and advanced composite materials. In the 1980s, SJTU began to develop selected programs in science, primarily of an applied nature, such as computational mathematics, mathematical economics, and applied and optical physics. The rationale was to supplement SJTU's traditional strength while expanding employment options for students. Since the mid-1990s, its effort has been focused on building humanities, law and business schools, as a result of following MOE directives, learning from top research universities in the West, and realizing the benefit of a liberal education to students. Again, most of the new programs tend to be more applied and include business management, international affairs, law, history of science, and scientific English (personal interview). In 1999, the Shanghai Agriculture College was merged into SJTU, allowing for a new opportunity to engage in life science research (later the creation of the

Table 2. *Fudan and SJTU at a glance (as of 2005)*

	Fudan University	SJTU
Year Founded	1905	1896
Academic Disciplines	14 schools in humanities, law, journalism, economics, management, information science, life sciences, pharmacy, nursing, basic medical sciences, public health, technology science and engineering, software, and international relations and public affairs	21 schools in agriculture, chemistry, engineering, environmental science, foreign languages, humanistic and social sciences, international and public affairs, law, life science, management, media and design, pharmaceutics, and software
Academic Programs	67 undergraduate programs, 148 master's programs, 103 doctoral programs, 22 postdoctoral programs	60 undergraduate programs, 152 master's programs, 93 doctoral programs, 21 postdoctoral programs
National Key Laboratories	• Genetic Engineering • Applied Surface Physics • ASIC & System • Medical Neurobiology • Materials Modification by Laser, Ion & Electron Beams	• Laboratory of Ocean Engineering • Laboratory of Vibration, Shock & Noise • Laboratory on Fiber Optic Communication Networks & Advanced Optical Communication Systems • Laboratory of Metal Matrix Composites
Ministry of Education Key Laboratories	• Molecular Engineering of Polymers • Nonlinear Mathematic Models & Methods • Applied Ion Beam Physics • Bio-diversity & Ecological Engineering • Studies of Carcinogenesis & Invasiveness	• Thin-film & Microfabrication Technology Lab • High Temperature Materials & Measurement Lab • Power Machinery & Engineering Lab
Other Ministerial Key Laboratories	Ministry of Health • Molecular Virology • Glycocojugate • Functional Reconstruction of Hand • Hearing • Clinical Pharmacology of Antibiotics • Viral Heart Diseases	Ministry of Communications • Underwater Technique Lab Open Laboratories of "863"Project • "863"CIMS Technological Design Automation Engineering Lab • "863" Intelligent Robot Assembly System Network Lab

Sources: http://www.fudan.edu.cn/ (retrieved April 28, 2005) and http://www.sjtu.edu.cn/www/english/ (retrieved April 28, 2005).

School of Life Sciences). A School of Pharmacy has been jointly managed with the Shanghai Institute of Pharmaceutical Industry (http://www.sjtu.edu.cn/www/english/, retrieved April 28, 2005). SJTU also established a medical school in the hope to merge with a local medical university, and eventually took in Shanghai No. 2 Medical University in the summer of 2005. [15]

The expansion of academic programs in Fudan and SJTU has been accompanied by a rapid rise in student enrollment, particular those pursuing master and Ph.D. degrees (see Table 3). Both universities are looking into new ways to enhance student learning and research experience. For example, SJTU is moving toward an multidisciplinary approach. It is encouraging students to take courses, even majors, in fields outside of engineering, such as business management. Fudan began to allow students to change their majors in 2002, a practice unseen in most Chinese universities by then. This shows that Fudan is prepared to adopt more flexibility in managing education. Since 2004, Fudan has gone a step further to set up a University College to provide instructions to all freshman students, who would declare a major only in their second year no

Table 3. *Student enrollment and university personnel, 1985–2003*

	1985–86	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Fudan university[a]											
Degree students	–	–	11,062	11,861	11,501	12,388	13,419	19,968	22,984	25,138	26,327
Undergraduate	–	–	8,309	8,710	8,183	8,623	9,064	13,456	14,791	15,738	16,179
Master	1,049	1,189	2,146	2,381	2,473	2,790	3,185	4,537	5,727	6,538	7,016
Ph.D.	98	231	607	770	845	975	1,170	1,975	2,466	2,862	3,132
University personnel	–	–	4,673	4,589	4,543	4,465	4,337	6,229	5,957	5,839	5,974
Regular faculty	–	–	1,396	1,401	1,408	1,370	1,296	1,902	1,994	2,097	2,143
Research faculty	–	–	767	715	720	632	669	588	389	–	–
Staff and affiliates	–	–	2,295	2,265	2,210	1,938	1,895	2,992	2,871	–	–
Enterprise employees	–	–	215	208	205	525	477	747	703	–	–
SJTU											
Degree students	9,077	11,916	13,346	13,429	13,676	14,386	18,033	20,371	20,914	25,118	28,340
Undergraduate	7,511	10,645	11,081	10,890	10,845	11,069	13,933	14,806	15,349	15,752	15,552
Master	1,451	1,132	1,801	1,863	1,956	2,327	2,926	4,039	4,039	7,052	9,790
Ph.D.	115	139	464	676	875	990	1,174	1,526	1,526	2,314	2,998
University personnel	–	–	–	5,785	5,741	5,461	5,753	5,664	6,374	6,227	6,380
Regular faculty	–	–	–	2,501	2,889	2,291	2,237	2,355	2,403	2,586	2,766
Research faculty	–	–	–	201	195	174	421	397	259	263	343
Staff	–	–	–	2,072	1,730	1,992	1,589	1,570	1,781	1,789	1,856
Enterprise employees	–	–	–	1,011	927	1,004	1,506	1,342	1,931	1,589	1,415

–: Data not available.

Sources: Fudan and SJTU Yearbooks, various years.

[a] Shanghai Medical University was merged into Fudan in April 2000. Data for 2000 and onwards reflect this.

matter what choice they have made during the national college-entrance exams (personal interview).[16] Fudan also has established the "Student Scientific Research Fund" and the "Student Summer Fieldtrip Fund," to encourage student engagement in research and experiential learning (http://www.fudan.edu.cn/, retrieved April 28, 2005).

Fudan and SJTU have worked to cater their teaching and training programs to the needs of the local labor force. In addition to traditional continuing education opportunities, they offer programs for professional certificates and teaching by correspondence programs. Students in some of the extension programs can even take specialized courses. Both also have developed distance-learning programs. Fudan has even set up a new school to manage online education, which offers courses in the subjects of English, computer networking and programming, economics and management, and college entrance-exam as well as civil-service exam preparation (http://www.fudan.edu.cn/, retrieved April 28, 2005).

Both universities have established a wide range of exchange programs with overseas institutions with instructional and/or research content. Fudan has exchange relations with 82 colleges and universities in 13 countries and regions. Following a popular practice, Fudan's management school has developed joint programs including the Fudan-Columbia University Executive Development Program and Fudan-Hamburg MBA Double Degree Program (http://www.fudan.edu.cn/, retrieved April 28, 2005). Another very promising example of educational exchange is the Nordic Center, a joint project between Fudan and 17 universities from four Nordic countries. Officially opened in November 1995, it is the only center for Nordic studies set up in China to promote closer ties and understanding between the Nordic countries and China through various joint research projects and educational activities. Similarly, SJTU has exchanges with over 100 universities in more than 20 countries and regions, and has invited many overseas scholars as visiting professors. Its management school now offers joint MBA programs with the University of the Sunshine Coast (Australia), Nanyang Technological University and Marseille School of

Management, with varying focus on finance, international business and global management strategy (http://www.sjtu.edu.cn/www/english/, retrieved April 28, 2005).

Building intellectual capacity by recruiting top-notch faculty through competitive mechanism also is high on the agenda for both universities. Since 2003, domestic and international professionals can apply for newly created professorial positions (more than 300) in Fudan, as the university launches human resource reforms. To accomplish this, Fudan has even set up a new Talent Recruitment Office responsible for recruiting outstanding scholars, selecting candidates competing for MOE Chair Professorships, and providing support services to new recruits. SJTU has had a similar recruitment program since 2004, currently with close to 300 professorial positions open. Unlike Fudan, SJTU relies on individual schools and departments in screening and recruiting candidates. Such competitive recruitment mechanism is a welcome development and will likely increase academic quality and diversity, since most elite Chinese universities have a longstanding tradition of hiring their own graduates.

The research capacity of Fudan and SJTU has increased partially as a result of academic expansion as well as open faculty recruitment. There is a steady growth of publications in internationally recognized journals and proceedings in science and engineering (see Table 4). With its strength in sciences, Fudan scores higher in the Science Citation Index Expanded (SCIE), while its recent diversification into engineering also shows promising results in the Engineering Index (EI). SJTU fares significantly better in EI because of its distinction in engineering and is catching up rapidly in SCIE. By all accounts, SJTU appears to lead in research publications and domestic patents since 2000, though it also has a slightly larger faculty (see Tables 4 and 5). Its standing at the national level also has improved more markedly, ranking seventh in SCIE, second in EI, third in ISTP (Index to Scientific and Technical Proceedings) and second in patents in 2001 among all Chinese universities (SJTU Yearbook, 2003, p. 12).

The improvement in research output also can be attributed to the stronger incentives SJTU administration provides for faculty research and publication. For instance, with each SCIE

Table 4. *Research output in science and engineering disciplines, 1993–2004*

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fudan university[a]												
Publications	–	–	436	421	600	538	638	876	–	1,182	1,875	–
SCIE	–	–	244	230	320	308	442	612	648	773	944	–
EI	–	–	135	124	216	154	196	190	–	255	730	–
ISTP	–	–	57	67	64	76	–	74	–	154	201	–
Patents	13	8	15	19	15	22	28	101	196	247	265	133
New invention	10	4	10	16	12	21	21	88	177	226	224	120
New application	3	4	5	3	3	1	7	13	19	21	40	13
New design	0	0	0	0	0	0	0	0	0	0	1	0
SJTU												
Publications	148	162	144	164	203	277	610	1,202	1,669	2,333	–	–
SCIE	76	52	64	53	62	113	177	389	589	744	–	–
EI	72	110	80	111	141	164	349	649	842	1,128	–	–
ISTP	–	–	–	–	–	–	84	164	238	461	–	–
Patents	9	15	10	10	5	11	17	142	160	219	504	400
New invention	5	7	3	6	5	5	5	97	132	193	482	371
New application	4	8	7	3	0	6	12	44	28	26	22	29
New design	0	0	0	1	0	0	0	1	0	0	0	0

–: Data not available.
SCIE = Science Citation Index Expanded, EI = Engineering Index, ISTP = Index to Scientific and Technical Proceedings.
Sources: Fudan and SJTU Yearbooks, various years; China Patents Database, various years.
[a] Shanghai Medical University was merged into Fudan in April 2000. Data for 2000 and onwards reflect this.

Table 5. *University enterprise and technology transfer values, 1996–2003*

	1996	1997	1998	1999	2000	2001	2002	2003
Fudan University								
University enterprises (million RMB)								
Sales revenue	98.0	130.0	193.5	794.3	1157.0	1408.5	–	–
Profit	15.1	27.6	33.7	85.4	131.9	194.7	–	–
Contribution to university	–	–	–	38.7	54.4	58.4	–	–
Contribution through national taxation	–	–	–	34.0	52.7	70.2	–	–
Total assets	–	–	–	1808.0	2624.0	3107.8	–	–
Net assets	–	–	–	1046.0	1632.0	1752.0	–	–
Technology transfer contracts (million RMB)	–	–	–	–	–	76.9	–	73.3
SJTU								
University enterprises (million RMB)								
Sales revenue	–	573.1	715.5	–	–	1646.2	1786.4	2185.0
Profit	–	70.9	97.0	–	–	167.7	163.8	243.0
Contribution to university	–	12.4	10.5	–	–	–	–	–
Contribution through national taxation	–	49.8	67.6	–	–	–	–	–
Total assets	–	1929.6	845.4	–	–	5479.6	5910.0	6742.3
Net assets	–	784.5	369.0	–	–	3222.4	3399.1	3726.0
Technology transfer contracts (million RMB)	53.0	61.2	76.7	85.6	155.6	112.1	164.2	224.5
Contract or joint R&D	36.4	43.2	–	–	–	80.1	101.4	151.0
Technical services	15.1	17.2	–	–	–	27.3	55.7	62.8
Consulting	1.1	0.7	–	–	–	4.7	7.0	1.9
Licensing	0.4	0.1	–	–	–	–	0.1	8.7

–: Data not available.
Sources: Fudan and SJTU Yearbooks, various years.

publication faculty is entitled to a 10,000 RMB reward with 9,000 as research grant and 1,000 as cash incentives (personal interviews). Fudan offers somewhat less incentives, ranging from 9,000 RMB for an SCIE I publication, 6,000 for SCIE II, 4,000 for SCIE III to 2,000 for SCIE IV (Fudan S&T Yearbook, 2003, p. 47). In addition, both universities offer cash incentives to faculty who have won national and local research and technology awards. More importantly, motivation for research comes in the way through which faculty annual evaluation is carried out. Much like the commune system started in the late 1950s, faculty needs to meet an annual work load quota that includes courses offered, publication and supervision of graduate students. Those with a higher research output can easily substitute publications for teaching, a practice similar to that in top US universities where research is more valued. In fact, many full professors never have to set foot in an undergraduate classroom while some teaching faculty is so burdened with courses that they rarely have time for research; hence creating a stratified faculty rank. Some university officials also complain about another downside of the incentive system—certain faculty members divide up research results so as to maximize the number of publications (personal interviews).

4. CULTIVATING UNIVERSITY–INDUSTRY LINKAGES

In addition to the common mechanism of technology transfer through licensing and other similar arrangements, Chinese universities often are directly involved in enterprise operation. The tradition of university enterprises actually dates back to the late 1950s when they served as sites for student experiential learning and generators of employment as well as supplemental funding for universities (Ma, 2004). It is only after the mid-1980s that the commercialization of faculty research became a key function of university enterprises, although even today the majority of them are not technology enterprises. As in many top universities in China, Fudan and SJTU use separate administrative units to manage traditional technology transfer (often by the S&T division or its affiliate) and university enterprises (by a university enterprise office or group).

SJTU's distinction in engineering offers a clear advantage in traditional technology transfer since results from faculty research are closer to the stage of commercialization, while basic or applied scientific research in Fudan requires a much lengthier path to commercialization. This difference is reflected in the significantly higher contract values for SJTU through joint or contract R&D, technical services, consulting and licensing (see Table 5)—all managed by a national technology transfer center (one of the six in the country). Officially launched in November 2001 with a staff of over 20, the center is affiliated and works closely with the university's S&T division (*ke ji chu*). [17] Unlike its counterpart in Qinghua University, the center is not involved in university enterprises. Rather, it uses proactive approaches to identify marketable innovations patented by faculty, to cultivate collaborative relationship with firms (e.g., Volkswagen, General Motors, and Baoshao Steel), and to raise research funding from local government sources. Its footprints extend beyond Shanghai into the Yangtze River and Pearl River Delta regions, through the establishment of branch offices and information exchange centers. In fact, funds from local governments have become an increasingly important source of research expenditure for SJTU (from just over 5% in 1996 to over 20% since 2000) while the share of funding from outside firms has declined from 63% to 33% (see Table 6). By comparison, Fudan's operation of technology transfer has so far been limited to three staff members in its S&T division. As a result, they can only manage to provide general oversight and are unable to work closely with faculty or firms (personal interview).

Licensing has yet to become a major mechanism of technology transfer. According to an SJTU center manager, only about 10% of all patents registered by the university are marketable (personal interview). It is rare that faculty gets to continue to work on an embryonic technology after the basic concept has been licensed out. Once a licensing contract is complete, SJTU faculty gets 60% of profits, school/department 20% and university 20%. Given such a preferential distribution, some faculty still prefers to work with firms directly instead of licensing to maximize income. Unlike many MNCs, most domestic firms do not plan ahead for new product lines or technology. When research is still at an early stage and its commercial potential has yet to be fully perceived, these firms are unwilling or unable to pursue devel-

Table 6. *Research funding and sources in SJTU, 1996–2003*

	1996	1997	1998	1999	2000	2001	2002	2003
Amount of funding (million RMB)	16.3	402.9	226.6	294.2	447.7	425.9	267.0	756.4
Ministry of Education	8.3	167.0	69.8	110.1	502.1	450.1	675.8	831.4
Ministry of Science and Technology	9.6	354.5	113.8	116.8	204.0	221.9	333.0	881.8
National Science Foundation	2.0	59.5	62.3	82.1	108.9	128.5	227.3	269.3
Other central ministries	17.5	100.1	99.4	52.6	132.2	502.5	689.1	707.1
Local government funding	9.1	66.1	110.4	211.8	1226.4	1995.3	1963.0	1920.9
Enterprise contract funding	107.3	1141.8	1720.4	1714.8	1766.4	2422.1	2278.3	2921.4
Funds converted from other income	1.1	10.5	56.3	224.9	609.6	110.1	364.6	474.3
Bank loan	0.2	1.1	1.1	1.0	0.0	0.0	0.0	0.0
Overseas funding	16.3	402.9	226.6	294.2	447.7	425.9	267.0	756.4
Other	0.0	0.0	0.0	0.0	49.6	24.2	118.5	38.2
Total	171.4	2303.5	2460.0	2808.2	5046.9	6280.6	6916.6	8800.7
R&D funding	–	–	–	–	3650.0	4860.0	5160.0	6365.9
Share (percent)								
Central government sources	21.9	29.6	14.0	12.9	18.8	20.7	27.8	30.6
Local government sources	5.3	2.9	4.5	7.5	24.3	31.8	28.4	21.8
Enterprise contract funding	62.6	49.6	69.9	61.1	35.0	38.6	32.9	33.2
Other domestic sources	0.8	0.5	2.3	8.0	13.1	2.1	7.0	5.8
Overseas funding	9.5	17.5	9.2	10.5	8.9	6.8	3.9	8.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

–: Data not available.
Sources: Fudan and SJTU Yearbooks, various years.

opment. For this reason, Fudan has encountered difficulty in licensing patents with more science content. The university also has discouraged faculty from collaborating with small and medium-sized enterprises (SMEs) because of their low technology content and the large amount of time needed to train their staff in order to do collaborative R&D (personal interview).

Joint R&D collaboration appears to be a major mechanism for the two universities to connect with overseas firms and institutions. SJTU has formed joint laboratories with 40 MNCs and research institutions to train personnel and work on major projects. Its collaboration with General Motors (GM) is perhaps the most comprehensive and supports GM's operations in Shanghai, including five joint research centers, targeted training (undergraduate students go through three years of basic training and then specialized training in the fourth year), thesis research by graduate students, and reciprocal appointment of R&D staff. [18] SJTU also has a wide range of connections with Japan and Korea. Over 300 SJTU faculty members have studied in Japan, and they are the bridges to attract research investment from Japanese companies or conduct joint R&D with universities. [19] Some SMEs from Japan want to open up the market in China but are reluctant to locate in the inland areas. SJTU works with them to transfer technology to Chinese firms and even organizes visits by Shanghai firms to these Japanese SMEs (personal interview). In fact, a significant component of joint R&D is redevelopment of foreign technology by SJTU faculty to cater to Chinese firms and markets. Fudan's collaboration with MNCs is more recent and less extensive, including an R&D partnership with Axcelis Technologies Inc., a joint Fudan-Novellus research center in microelectronics, a Fudan-IBM research center on IT, and a Fudan-TU Delft International Institute of Microelectronics (Fudan S&T Yearbook, 2003, p. 33). This is an encouraging development for Fudan as foreign firms in Shanghai had drawn very little upon its research abilities, relative to their availability to Chinese firms. Earlier cooperation with Fudan professors was frequent but primarily for market assessment purposes (Walcott, 2003).

Using faculty research and innovation as knowledge capital to enter into enterprise operations is a far more significant mechanism to build commercial linkages than traditional technology transfer through licensing, particular for Fudan. Key university officials have recognized the lack of technology transfer intermediaries and instead spearheaded an ambitious university enterprise program that has won a degree of distinction in China. [20] Using technology stock/share to form joint ventures with other business interests is the main form, and there is no university enterprise solely owned by Fudan. It has chosen, by the decision of the university president, not to make direct financial investment from the university budget in any enterprise, except for a small incubator one-year grant program for small startups by its own graduates and selected faculty. 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/departments were closed, merged or transformed into free-standing enterprises and moved off the campus (*Chinese University Technology Transfer*, October 2002, p. 19). This attempt has been aimed to maximize the accountability of the surviving enterprises, minimize the potential impact of business activities on academic culture, and to further win over the support of top administrators for university enterprises. [21]

A Commercialization and University Enterprise Management Office has been established in Fudan to promote research spin-offs, manage assets operation as well as spin-off enterprises, and provide necessary business services. The Office also is the legal representative for the university in all spin-off enterprises and oversees the planning of Fudan's science park (http://sp.fudan.edu.cn/xc.html, retrieved May 1, 2005). More importantly, it hopes to brand the "Fudan" name through these enterprises and form a high-tech industry cluster centered around them. Fudan's guiding principle here is that the university should cultivate high-tech enterprises the same way as it educates students. The Office now is involved in more than 100 enterprises, which together contribute 70–80 million RMB to the university annually and employ around 800 people or about one-fifth of university staff (personal interview). Outside firms also participate in holding companies with Fudan (Walcott, 2003). When university enterprises become mature businesses, some even go public as in the case of Fudan Fuhua

Pharmaceuticals that became China's first public company with university-controlled shares in 1993 (Yang & Xu, 2004). Another good example is the Shanghai Fudan Microelectronics Company Limited established in July 1998. Unlike most of the enterprises affiliated with Fudan, it draw cash investment from an IC (integrated circuit) research lab in Fudan, an outside investment firm, and several entrepreneurial employees, forming one of the smallest share-holding companies in China (*Chinese University Technology Transfer*, December 2004, p. 28). Under the leadership of a former Fudan graduate student, the company has concentrated its limited funding on product development and sales, in five broad categories of ICs for industrial applications. [22] The company went public on the Hong Kong Stock Exchange within two years of creation and set up a Hong Kong subsidiary in 2002. It is now considered one of the most advanced IC firms in China.

SJTU, on the other hand, uses a somewhat different approach to university enterprises. It has directly invested university funds in technology spin-offs and become the sole owner of some enterprises. All SJTU-affiliated commercial entities are under the oversight of the university enterprise group, of which the party secretary of the university serves as the chairman and president as vice chairman. As a result, university administration and enterprise decision-making are often intertwined. Some unsuccessful firms have to be bailed out by the university from time to time and, therefore, are seen as more of an intrusion to the traditional academic culture (personal interview). One of the more successful SJTU enterprises is the Angli Ltd., specialized in health supplements and created as a wholly university-owned entity in 1990 (Yang & Xu, 2004). Its products target the domestic mass market but have quickly established a brand name, leading to steady rise in sales revenue and making the company the most profitable enterprise for SJTU. [23] The company's rapid expansion also has necessitated the public offering, listed on the Shanghai Stock Exchange since 2001. The university now holds a 25% share.

Faculty in both universities, however, are yet to become fully supportive of university enterprises. Many feel that commercial interests may interfere with the long-term research agendas, particularly the emphasis on basic research. Faculty involvement in enterprises also depletes resources for classroom teaching, even though theoretically faculty is required to devote 80% of their time to university responsibilities (personal interview). Some even suggest that when professors become company executives, they should no longer hold faculty positions. More importantly, faculty promotion guidelines continue to give much less credit to commercialization than to scholarly publications. Yet the pull of financial gains is rather strong given that faculty salary levels remain moderate in general despite several efforts by the central government to raise them. The stronger likelihood of outside engagement for the more applied disciplines also has led to a situation in which faculty income can vary significantly across programs (personal interview).

While the campus debate continues on whether higher education ought to keep a distance from the market, both university administration have marched on to set up science parks as a vehicle for building high-tech clusters. In December 1999, the first State-level University Science Park by SJTU was officially approved by MOST and MOE as a pilot project, composed of three high-tech incubators. The Huigu Center, which lies preliminarily around SJTU's Xuhui Campus, mainly focuses on electronic information industry, new material and biotech, medical apparatus and instruments, optical–mechanical–electrical integration, and advanced manufacturing mechanics. The business services provided by the incubator include training and assistance in obtaining local or national innovation grants and applying for licenses and high-tech designation as well as relevant incentives (*Science & Technology Industry of China*, June 2002, p. 44). In addition, SJTU has partnered with Shanghai Venture Capital Corporation in setting up a small venture capital firm to invest in enterprises located in the incubators. Established in 2000, Fudan's Science Park now houses over 100 enterprises created by both Fudan researchers and other entrepreneurs. It is a joint effort between Fudan and several local entities (including Shanghai's Center for Technological Enterprises), and consists of a software park, a business incubator, a "digital city," an industrial estate, and two branch parks (http://sp.fudan.edu.cn/intro/main.html, retrieved May 4, 2005). The management of the park is undertaken by a holding company for which a Fudan vice president serves as the chairman of the board. Similar to SJTU's science park, this park is recognized by MOST as a State-level University Science Park and helps enterprises raise investment through establishing various venture-capital funds.

5. CONCLUSION

Both Fudan and SJTU have made significant strides in educational reform and technology transfer, in a relatively short time span. The trend toward university–industry cooperation has obvious positive implications for the dissemination and application of scientific and technological innovation in the Shanghai metropolitan economy and beyond. Their experience shows that the vitality of research universities and spin-off enterprises in China is shaped by a national innovation system, as well as the local policy and innovation environment. In particular, the critical policies determining the national R&D framework, investment priorities for institutions of higher education, and allowance for rewarding commercialization are largely decided by the central government. Fudan and SJTU's selection as recipients of both "211" and "985" has been crucial to their academic and resource expansion. Matching funds from the Shanghai municipality and incentives for establishing university science parks give them a further advantage over other local universities.

The universities are gaining greater autonomy in several spheres, such as academic programs and curriculum, administration, and fiscal matters, but are still far from autonomous (NSF, 2000). Fudan has spearheaded the effort to give students more choices in determining their majors, and both have adopted competitive mechanisms to recruit top faculty. Under the general framework set by MOE in designing new interdisciplinary research programs to be funded by the second phase of "985" Program, the universities have the latitude to decide how such programs may be formed and administered. Even when both have little choice but to promote university enterprises under central directives, they can and have used very different investment and management approaches. What seems to be a setback may be the degree to which they are now jointly managed by the locality. With municipal matching funds and incentives also come restrictive conditions that include, for instance, enrollment quotas for local students (about a third of annual enrollment of degree or non-degree students). The municipal government also requires the universities to quantify their contribution to the local economy, and has probably over-emphasized research commercialization (personal interview).

To a large extent, the success of university technology transfer relies on the quality of the local innovation environment. Fudan and SJTU are keen on licensing out patented research but officials remain frustrated by the lack of intermediaries and the limited capacity of local firms to conduct further development. Compared to universities in the West, both are significantly behind in utilizing traditional mechanisms of technology transfer, which tend to allow for less disruption of faculty research and teaching. It remains an open question whether there should be limits to university engagement in business activities, 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 appear to reduce this type of conflict as university administration is minimally involved in business activities and enterprises are given a freer rein for decision-making. Its philosophy can be summarized as self-incubation by the university, investment by outside entities, expansion by market principles, and maturation by going public. The direct involvement of university administrators in enterprises, for instance in SJTU, tends to bring with it a less flexible management practice as well as ambiguous ownership structure. Compounded by the proximity of enterprises to the campus, this has created a less desirable impact on the academic culture, especially when some of them are not engaged in R&D but in commercial activities.

The growth of university enterprises, and other local technology firms, is limited by the shortage of venture investment (particularly those with a pure focus on technology) in China. A number of enterprises founded by Fudan professors had to rely on personal and informal funds to finance initial operations (Segal, 2003). Worldwide experience shows that continuing investment in product development is essential in the growth of innovation. Startup firms, particularly those in developing cutting-edge technology, depend on venture capital to underwrite their early costs. Both the central and Shanghai governments have begun to acknowledge the importance of attracting foreign venture capital to link Chinese startups with international talent. State-backed venture capital firms also are being restructured in order to compete. This is one of the areas where further development is desirable and which will affect the course of both R&D and its commercialization.

NOTES

1. Patenting by US universities increased nearly sevenfold over the period of 1976–98 and licensing revenues from the sales of IP grew briskly as well (Owen-Smith, Riccaboni, Pammolli, & Powell, 2002).

2. Examples of such reforms include the enactment of the Technology License Offices Law in 1998 and introduction of the Japanese version of the Bayh–Dole Act in 1999 (Kodama, 2005).

3. The six universities are Qinghua University, SJTU, Xi'an Jiaotong University, East China University of Science and Technology, Central China University of Science and Technology, and Sichuan University (Xinhuanet, November 2001).

4. These debates were highlighted by six circulars endorsed by the Vice Premier Li Lanqing. It was after the selection of a new Minister of Education, Zhou Ji who himself oversaw a number of university enterprises as a professor in Wuhan, that the debates were brought to some closure with a clear official position (personal interview with a Fudan University official). This position states that the three major missions of universities are teaching, research, and commercialization (*Chinese University Technology Transfer*, October 2002, p. 10).

5. The Johns Hopkins University in Baltimore and the University of Washington in Seattle, for instance, have not significantly influenced the surrounding urban economies (Feldman, 1994; Haug, 1995; Mayer, 2003).

6. MOST's mandate was to regulate and coordinate activities in R&D institutes, production enterprises, and research centers in universities. However, MOE was also responsible for education and training in universities, as well as vocational and technical schools. The industrial bureaus—such as the Ministry of Communications and Posts, Ministry of Machinery, Ministry of Chemical Industry, and others—also oversaw research institutes as well as the production and distribution enterprises within their respective industries. See Liu and White (2000).

7. Specific targets included increasing the share of R&D expenditure in GDP (to about 2.5%), increasing number of patents and number of scientists and engineers, establishing 30 technological incubators, and raising the share of high-tech products in output value and export (Fan, 2003).

8. Although most developed countries' R&D/GDP ratios range between 2% and 2.5%, China now stands out as a heavy spender among developing countries with the largest R&D expenditures. Mexico's R&D spending, for example, was 0.4% of its GDP in 1999, while India's score was 0.86% in the same year.

9. The "863" Program aims to catch up with the West in fundamental and frontier research, while the Torch Program promotes commercialization of new technologies (Hu & Jefferson, 2004). All provinces have begun operating science parks with the help of the Torch Program. By 1998, there were 53 nationally sponsored (plus hundreds of locally sponsored) science parks in the country. Besides those in Beijing, Shanghai's science parks are the most developed (Hsiung, 2002; Suttmeier & Cao, 1999).

10. This Park, which will eventually cover 25 sq. km, had attracted $4.47 billion worth of investment by the end of 2000. The turnover during that year was close to $1 billion and has been rising rapidly as increasing numbers of foreign and private firms have been drawn to the park (Yusuf & Wu, 2002).

11. Private technology enterprises, on the other hand, counted for 86% of Shanghai's S&T related expenditures in 2003.

12. "985" Program's first phase funded only nine universities beginning in 1999, including Beijing University, Qinghua University, University Science and Technology of China, Nanjing University, Fudan University, STJU, Xi'an Jiaotong University, Zhejiang University, and Harbin Institute of Technology. The second phase expanded to include 34 universities in 2004 (Ma, 2004).

13. In July 1999, for instance, MOE reached an agreement with the Shanghai Municipal Government that provided Fudan University and SJTU with an increase of a 120 million RMB investment (http://www.fudan.edu.cn/, retrieved April 28, 2005). For SJTU, the total fund from "Project 211" amounted to 421 million RMB in the 9th Five-Year Plan period (1996–2000), including State Planning Commission 82 million, Ministry of Finance 38 million, Shanghai Municipality 120 million, MOE 45 million, and university matching fund 136 million. See http://www.sjtu.edu.cn/www/english/ (retrieved April 28, 2005).

14. The Medical Center runs 11 colleges or departments, 8 undergraduate programs, 22 research institutes, and 17 research centers. Its research is strong in the areas of molecular genetics, molecular virus, neurobiology, preventive medicine, and clinical medicine for liver cancer (http://www.fudan.edu.cn/, retrieved April 28, 2005).

15. SJTU had hoped to merge with the Shanghai Medical University, a stronger institution and a close-by neighbor. But municipal authorities decided to merge Shanghai Medical University with Fudan instead (personal interview).

16. Fudan's University College is very similar to the general education programs widely seen on US campuses, in which faculty from many units of the university provide course instructions and only a small core faculty are administratively located there.

17. The more traditional responsibilities of university S&T division (*ke ji chu*) include the management of research projects, development and extension of technology, IP management, management of research bases, and management of international research cooperation projects.

18. The first among several joint efforts is the GM-SJTU Technology Institute launched in 1998. It consists of R&D programs and a subsidiary Powertrain Technology Institute, which mainly focuses on engine and automatic transmission technology. The GM-SJTU institute offers more than 10 different classes designed specially for China in engine technology, engine controls and engine teardown, base automatic transmission technology, transmission controls and teardown (*M2 Presswire*, July 17, 1998). In 2000, GM and SJTU signed another agreement to establish the GM Body Manufacturing Satellite Lab, an extension of the GM R&D Satellite Research Laboratory at the University of Michigan in Ann Arbor. The new lab conducts joint research in body manufacturing, evaluation system improvement and manufacturing technical design (*PR Newswire*, October 29, 2000).

19. For instance, SJTU has collaborated with Japan's Kyushu University broadly, with Omeron on heart and blood pressure monitors, and with an environmental protection company on recycling mud from Suzhou Creek (personal interview).

20. This distinction is not based on the scale and sales of Fudan's enterprises, as in the case of Qinghua University. Rather it is the unique administrative philosophy and style that sets Fudan apart (personal interview).

21. In return, nearly all top university officials decided to support university enterprises in 2002, with a key condition that Fudan bears minimal financial risk but receives a sizeable payback from the enterprises. On the other hand, the support from schools/departments has always been strong as enterprises served as cash cows previously and their fiscal health suffered from the enterprise closings (personal interview).

22. Products developed and sold by the company can be classified into five categories—ICs for telecommunication products, smart cards, motor vehicle electronic products, power supply electronic products, and consumer electronic products (*Business Wire*, June 15, 2004).

23. Its original product was based on research done by SJTU's former Department of Bioengineering. Initial investment was largely research funding from faculty involved, but SJTU regulations only allowed shares to be owned by the university and management by faculty (*Chinese University Technology Transfer*, March 2005, p. 23). In 2002, Angli's profits reached 56.8 million RMB, counting for a third of all SJTU enterprise profits of 163.8 million RMB (SJTU Yearbook, 2003).

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