SHANGHAI – FROM DEVELOPMENT TO KNOWLEDGE CITY

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Summmary:

This report provides insights on the expansive development in Shanghai of human resources in higher education and the creation of a huge web of incubators, university science parks, district industrial parks, and various specialized development zones. With a total population of some 17 million and a GDP per capita of around US$3,000 the city planners expects that 2.5 per cent of its GDP will in 2005 be used for research and development. FDI in high technology and returning scientists in microelectronics illustrate the ambitions of Shanghai to become a knowledge city.

More than 140 foreign-controlled R&D laboratories have already been established in Shanghai. Their number and sizes will increase and also involve more basic research as the IPR regime improves. Shanghai will emerge as innovative knowledge region on the world stage that before 2020 will be competing with other global knowledge regions such as the Oxford-London-Cambridge triangle by attracting talent and creating new knowledge. This report highlights a rapid and continued expansion of higher education in Shanghai that now has 59 colleges and universities with a total enrolment in 2004 of 600,000 students

The City has 10 universities which are included in the national list of Top-100 Universities which have been selected by the Ministry of Education to receive special treatment and extra resources. Three of a dozen Chinese universities with expectation to become recognized as world-famous research universities are located in Shanghai – Fudan University, Tongji University and Shanghai Jiaotong University.

Fudan University Science Park and the School of Microelectronics at Fudan University provide examples of the changing character of the university system in Shanghai
Linked to the development of human resources is a web of technological infrastructure of which Zhangjiang High-Technology Development Zone provides an illustration of ongoing efforts to integrate industrial production, research and university education

Shanghai is attracting overseas entrepreneurs in its advancing semiconductor industry, exemplified by SMIC with one of its bases in Zhangjiang High-Technology Development Zone, Shanghai is also attracting returning scientists to expand its IC knowledge base as exemplified by the School of Microelectronics at Fudan University, which has 600 graduate students.

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KEWORD Human factors, Universities, Fudan University, Regional innovation System (RIS) Semiconductors, High Technology Parks, Overview of Science and Technology,

Shanghai – From Development to Knowledge City[1]

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Introduction

Shanghai's economic development is based on the twin pillars of knowledge creation and knowledge application. The last one has been strongly supported by the city's attraction to foreign investment in a wide range of industrial activities. The former one is coming to the forefront by a rapid expansion of higher education and scientific research, where foreign investors have also become active by setting up research laboratories.

The city enrols more than 50 per cent of its senior high school students to enter into colleges and universities. Three major universities among a total of some 60 colleges and universities have set the course to become recognized research universities by rapidly expanding its graduate training programs and attracting research funds.

Zhangjiang, the large high-technology park in Pudong across the river from old Shanghai, is known to almost everyone. In addition Shanghai also has a handful of expanding technology parks, aside from science parks attached to major universities. Each of the city's 11 districts has its own industrial park, most of them with a specific focus. Shanghai has 28 incubators, with at least one in each district, housing a total of some 20,000 companies.

These changes in Shanghai's technological and scientific landscape are not only top-down driven from the local government and supported by the central government in

[1] The preparation of this working paper has been made possible though a one-week study visit to Shanghai in early 2005. All my visit were facilitated through the office of Vice-Mayor Zhou Yupeng who kindly instructed The Foreign Affairs and Trade Commission of Shanghai Municipality to arrange the visits and interviews on which most of the this paper is based. Any mistakes or misunderstanding of information given is solely the responsibility of the author. A longer version of this report will appear rrs chapter 9 in the book "Technological Superpower China", to be published by Edward Elgar (UK) in November 2005

Beijing. Forces of change also originate from major foreign companies that are present in Shanghai with regional headquarters, production plants and more recently also with their R&D units. Shanghai has already registered more than 140 R&D units that have been established by foreign companies. Changes are also strongly driven by entrepreneurs, scientists and researchers in companies and universities who want to see their Shanghai emerge as a world metropolis for knowledge creation and knowledge application within the next couple of decades.

Shanghai expects that the high school student enrolment to college and universities will increase to 60 per cent and that the city by 2010 will have a total enrolment of 900,000 students in higher education. Graduate programs are rapidly expanding and major universities expect to handle an annual increase of some 15 per cent, which includes an ongoing continued shift to train more PhD students.

The role played by R&D is becoming important in Shanghai. Total investment in R&D reached RMB16.3 billion in 2003 which corresponds to 2.1 per cent of Shanghai GDP. In absolute term this is twice as much as in 2000. R&D as share of GDP is estimated to have reached 2.3% in 2004 and the objective is that it would reach 2.5% in 2005. Officials of the Development and Reform Commission indicate that investment of R&D would stabilize at this level as the economy in itself might continue to annually increase in the region of 10-15 per cent. The universities and high-technology parks, as described in this report are the most important instruments that Shanghai is making the most of to transform the city into a Knowledge City.

Shanghai Universities

Shanghai has altogether 59 institutions of higher learning of which 29 offer four-year training programs, while many of the others want to upgrade their curricula from usually three to four years. 23 of the institutions are available for foreign students. There are some 20 attached/hospital key S&T programs. Shanghai also 27 independently organized junior colleges for adult education.

The total number of students in institutions of higher education is close to 600,000 which correspond to 3.5 per cent of the population in Shanghai. There are 16 private-run colleges and universities. The number of university and college students in these institutions has reached 40,000 students which accounts for almost seven per cent of total students in higher education institutions. In 2003 the gross enrolment ratio was 53 per cent, which means that more than one half of alls students leaving senior high schools continue their studies in colleges or universities. A few years ago the enrolment rate was slightly above 40 per cent and it is expected to increase to 60 per cent in the future with a total enrolment in the Shanghai region of 900,000 students

Another source says that one out of every 10 university students in Shanghai were in 2003 pursuing their studies at private universities[2]. A municipal education department official said that Shanghai now has over 1,800 private and non-government funded educational institutions, including 40 private institutes and several hundred colleges providing higher education without diplomas. Most private universities want to recruit

[2] Growing role for private education, China Daily, July 9 2003

higher management staff and faculty from the prestigious local public universities to make their universities more compelling to students.

One examp0le is the Shanghai Fuqiu Vocational Studies College, which was approved in mid 2003 is located in the Pudong Lujiazui financial trade zone. Its President Hu Aiben was formerly the assistant to the president of Fudan University. Many teachers at Fuqiu come from Shanghai Jiaotong University, Shanghai University of Finance and Economics and Shanghai University. According to plans students will get professional training diplomas after three years' study here, on the assumption that they pass examinations organized by Fudan and Tongji universities. Fuqiu College has applied for certification to offer four-year degrees.

Entrepreneurs investing into education today are doing it as a business enterprise, rather than as a donation. Says Xu Xincai, one of Fuqiu College[3]: "The education industry has a bright future, although it takes a longer period of time to receive a return on the investment." The Law on Private Education Promotion, passed at the end of 2002, stipulated that "private school investors can get a reasonable repayment after deducting schooling costs and reserving development funds and other expenses."

The pentagonal area of Yang district in Shanghai contains a concentration of some ten universities and colleges with more than 100,000 students. Major campuses of four 211 universities are located here – Fudan University, Tongji University, Shanghai University of Finance & Economics, and The second Military Medical University.

Talent recruitment is very important for the university system and Shanghai is scouting all over the country as well as overseas. This is facilitated by additional funds coming from the “society” to fund additional costs. Rebuilding campuses is an important task for which funds are flowing not only from the government but also from the society. A recent educational policy has included the acceptance of private funds, often from overseas Chinese to attract highly qualified staff to key positions – with Zhangjiang Honor Professor as an important scheme

Zhangjiang professors are seen as important to link key personalities with key subject areas in a university. These include lectureships as well as program leaders, with a dominance of the latter category. Contract period is often five years, and many have remained within the program that started in the mid-1990s – earlier than the 985 program. There are some 40-50 Zhangjiang professors in Shanghai who have been recruited both domestically and overseas. There are a number of challenges for Zhangjiang professors as they have to adjust to a new environment where cultural clashes may occur. The may be successful in their scientific fields even if they are not completely successful as leaders in their fields. An example of the Zhangjiang Professor Program is given for the School of Microelectronics at Fudan University.

In addition the central government has since 1998 carried out the 985 project which covers 30 universities which has the aim to create fundamentally very strong universities. Three universities in Shanghai are included in this program – Fudan University, Tongji University and Shanghai Jiaotong University.

[3] Ibid.

Fudan University

Fudan University is composed of 17 schools offering a complete range of majors and disciplines, undergraduate programs, master programs and doctoral programs. The university has 5 national key laboratories, 57 institutes and 80 research centres. Eight of the undergraduate programs have been designated as the national centres for basic scientific research and teacher training[4]. Total enrolment of Fudan University is close to 40,000 students. The 2,100 faculty members of Fudan University include more than l,300 professors and associate professors, of which 24 have been admitted as members of the Chinese Academy of Sciences or members of the Chinese Academy of Engineering. The aim is to build .Fudan into a high-level research-oriented university, with a comprehensive range of academic disciplines to become one of the influential universities in the world.

Fudan University is today a well-recognized university that started in 1905 on a very modest scale as Fudan College – founded by Father Ma Xiangbo. The turmoil created after the 1911 Revolution forced Fudan to suspend education as funds and premises were lacking, and it did start again from March 1913. During 1912-16 Fudan issued 150 general certificates of education. It was generally referred to as Fudan Public School.

In 1917 Fudan College started its undergraduate program and was renamed Fudan University, and the number of students increased gradually. Subsequently Fudan University founded Art Department, Science Department, Business Department, Preparatory Department as well as a high school. The number of students reached almost 500 in 1921 which was also the year when the Institute of Psychology was founded. It was at the time a private university.

In 1929, Fudan University carried out reorganization and established departments of Journalism, and Law and Education. By 1937, Fudan expanded its activities to also include an affiliated middle school and a campus school as well as two compulsory elementary schools. With the Japanese control over Shanghai the Ministry of Education in Nanjing ordered Fudan to join three other universities – Daxia, Datong and Guanghua – and to leave Shanghai. Fudan University together with Daxia was able to make the move and students and teachers arrived in Chongqing at the end of December 1937. In February 1938, Fudan reopened near Chongqing.

Subsequently departments of geography and history, mathematics, statistics, agriculture, horticulture, farm, gardening technology were added and the university founded an Institute of Agriculture in 1940. The following year the Government decided that Chongqing Fudan University would change from being private to publicly-owned university. Teachers and students returned to Shanghai in August 1946. Towards the end of 1948 the Kuomintang Government planned to move the university to Taiwan.
Under the educational reform of 1952 certain areas of training were abolished while departments related to the art and science that originally belonged to another ten

[4] The establishment of the "Student Scientific Research Fund" and the "Student Summer Fieldtrip Fund," together with a hundred high-level lectures, a hundred recommended books, a hundred social fieldtrips and experiments in laboratories, constitute the "three hundred plan" which dominates campus activities.

colleges was merged into Fudan. After the reform of 1978 Fudan develop to an international comprehensive university to include humanities, social sciences, natural sciences, engineering sciences and management sciences. A further consolidation took place in April 2000 when Fudan University merged with the Shanghai Medical University. Fudan University is now under the direct jurisdiction of the Ministry of Education.

Fudan University is jointly funded by the Ministry of education and Shanghai Municipal Government. The total income in 2003 was RMB1,581 million with an increase of 30 per cent over the preceding year. Income sources were

- Ministry of Education 27%
- Shanghai Municipal Government 6%
- Educational undertakings 27%
- Research funds 19%
- Donations 6%
- Return on industrial spin-off 1%
- Interest on investment 2%
- Other sources 12%

Faculty and staff salary use 26% of funding with another 15% for their welfare, administrative costs requiring 27% and 12% were used for equipment.

Aside from its own research institutes Fudan has four sets of key laboratories which are directly supported by the national government[5]. Major key laboratories, supported by national agencies, are listed below.

State Key Laboratories
- Genetic Engineering (SKLGE) - Applied Surface Physics - ASIC & System - Medical Neurobiology - Advanced Photonic Materials and Devices
Ministry of Education Key Laboratories
- Applied Ion Beam Physics Laboratory - Biodiversity Science and Ecological Engineering - Non-Linear Mathematic Model and Methods - Molecular Engineering of Polymers - Medical molecular Virology - Molecular Medicine - Studies of Carcinogenesis and Invasiveness - Wave Scattering and Remote Sensing Information
Ministry of Health Key Laboratories
- Glycoconjugate Research - Antibiotics and clinical Pharmacology - Functional Reconstruction of Hand - Medical Audiology - Viral Myocardical Diseeases

[5] Fudan University brochure, undated

- Study of Myopic Eye

Ministry of Education – Key Research Bases of the Humanities and Social Sciences

- Centre for Ancient Chinese studies
- Centre for Chinese Historical Geography Studies
- Centre for Contemporary Western Marxist Studies
- Centre for Chinese Socialist Market Studies
- Centre for American Studies
- Research Centre for Information and Mass communication
- Institute of World Economy

Department of Microelectronics

The School of Microelectronics at Fudan University is a big department with a focus on advanced IC technology. The department has around 600 graduate students and good contacts with semiconductor foundries in the Shanghai region, such as Grace and SMIC in the Zhangjiang Semiconductor Industry Park. The ability of doing excellent research is exemplified by the success of an integrated circuit[6], known as Zhongshi No.1, for which the School was the independent designer. This is an illustration of China's ambitious to capture leading-edge technologies significant commercial potential[7].

Analysts say that mass production of the cost-effective chip will be an enhancement to China's digital TV industry, and is reported to be adaptable to international as well as domestic standards and cost-effective compared with similar international products. The chip embodies the core technology for the new generation high definition television (HDTV) that has been the focus of research and development, not only in China but worldwide since the early 1990s. The domestic importance lies in the fact that being the world's most populous nation. China has more than 370 million TV sets and an average 40 million sets are being sold each year. Furthermore, China plans to broadcast the 2008 Beijing Olympics with digital TV and to popularize digital TV nationwide by 2015[8].

The attraction of the Fudan University and Department in particular was certified by Professor Dian Zhou of the University of Texas at Dallas (UTD) who in late 2003 was appointed Dean of the School of Microelectronics at Fudan University. He was invited a Chang Jiang Scholar Award to his alma mater where he received his physics B.S and M.S. degrees in 1982 and 1985 respectively. Including his doctoral studies he spent 19 years in the US and is on leave of absence from UTD to develop and expand microelectronics at Fudan University. Zhou is appointed by Fudan University in agreement with the Ministry of Education and the Chang Jiang Honor Program that has made such appointments in several other Chinese universities.

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[6] China makes its first self-designed digital TV chip, China Daily, December 12 2004 http://www.chinadaily.com.cn/english/doc/2004-12/27/content_403686.htm

[7] There are three competing groups that are vying for the successful design of chips to be used in future digital HDTV sets. One is the microelectronics researchers at Fudan University who are collaborating with colleagues at Tsinghua University in Beijing. The other two are Shanghai Jiaotong University and the Shanghai Video & Audio Electronics Group, commonly referred to as SVA, which is a state-owned company.

[8] Ibid.

The award rules require the holder to have a doctoral degree, an outstanding record in research, internationally recognized and being able to develop a first-class research program. The award is sponsored by the Ministry of Education with additional funds from an industrialist in Hong Kong, Mr Jiacheng Li, and other generous sponsors. It is an ambitious program to rapidly develop China's research universities. Fudan is one of them and has been given the task to develop advanced microelectronics research capability.

In October 2004 the School of Microelectronics received a special grant of RMB100 million to establish a "Micro-Nano Electronic Platform". This is part of ambitious government objectives and is related the National Key Laboratory on Application-Specific Integrated Circuits (ASIC) already in operation at Fudan University. This laboratory has been in operation for more than ten years and been responsible for the development of 32 bit CPUs.

The equipment and resources of the Platform will be open to researchers from all over China who will be accepted on bases of qualified proposals and will bring their own financial resources. The platform activities will have five focal areas which include telecommunications and HDTV, System-on-Chip (SOC) high-level clean rooms, and electron-beam technology. Furthermore, substantial financial support has also come from commercial companies which include Applied Materials and Novelius Systems (Shanghai).

Professor Zhou perceives the development of the semiconductor industry in China to be in a very exciting stage. Although IC design capability is still low Chinese engineers/developers are rapidly catching up, and there are several favourable conditions for China to move forward. First, the timing is ripe as advanced foundries are moving to China. Second, the earlier IT bubble in the US and elsewhere, led to a recession within the electronics industry. As a result, many Chinese engineers and researchers who have been studying and working in the US, maybe for some 20 years, are not only willing but also eager to return to China. This cohort of willing returnees includes highly qualified engineers who can seize exciting and challenging tasks in China. Professor Zhou sees the development of the HDTV chip at Fudan as a good illustration.

However, Professor Zhou emphasizes that the returnees are also facing serious challenges and hardships. First, the scientific and technological infrastructure still remains weak. Although China offers ample talented manpower (researchers) the infrastructure for advanced research is still weak and is posed at the level somewhere between a developing country and an advanced industrialized nation. Second, the management culture in China is not only providing shortcomings but is often the root of serious cultural clashes and conflicts. However, there are many possibilities for carrying out exciting projects in China by introducing returnees in teams that get generous funding from national and local sources. Zhou has already recruited six faculty members from overseas – four from the US, including one former Motorola employee, and two from Europe. If everything goes well Zhou expects to have 20 returnees out a total faculty of some 60 staff members.

Professor Zhou stresses that the project that he is engaged in, as well as many others, are part of an ongoing experiment that is, so far, only taking place at a small number

of the leading universities in China. He anticipates that culture and management are going to change rapidly under the influence of the returnees.

Fudan Graduate School[9]

Graduate education was resumed in 1978 and has expanded rapidly. 1978 and 2001, the University has admitted 24,852 graduate students, among whom 19,854 were Master students, and 5,898, doctoral students. The university has awarded 2,991 Ph.D. and M.D. degrees and 12,313 master degrees by the middle of 2001

The Graduate School of Fudan University is the successor of the graduate schools of former Fudan University and former Shanghai Medical University, both of which are among the first 22 universities that were authorized to establish graduate schools after the graduate education system in China in November was resumed 1984.

A multi-discipline structure for cultivating graduate students has been formed, and it includes the disciplines of humanities, social sciences, sciences, engineering and medicine. Doctor degrees and Master degrees can be granted in 103 and 148 secondary disciplines respectively. Five types of professional degrees -- Masters of Business Administration, Juris Masters, Masters of Public Administration, Masters of Engineering, Masters and Doctors of Medicine can be granted. There are 22 post-doctoral stations, 29 state key subjects and five state key laboratories, which support graduate training.

Table 9.1
Fudan University Enrolment[10]

	Undergraduate students	Master & PhD students
2000	12,559	5,115
2001	13,241	8,193
2002	14,194	9,400
2003	15,170	10,148
2004	14,998	11,029

Source: Foreign Affairs Office, Fudan University

Tongji University is together with Shanghai Jiaotong University one of the three universities that have been singled out to become recognized research universities in Shanghai. Such an ambition is also reflected in the expansion of its Graduate School. See table.

[9] Fudan University web site (January 28 2004)
[10]

Table 9.2
Graduate students of Tongji University

Class Year	Doctor	Master	Total number of Enrolment	Total number at school		
				Doctor	Master	Total
1978		69	69		**69**	**69**
1988	30	322	352	**105**	**1116**	**1221**
1995	139	492	631	**255**	**1382**	**1637**
2000	364	1919	2283	**840**	**2845**	**3685**
2001	510	2006	2516	**1152**	**3777**	**4929**
2002	559	2145	2704	**1433**	**4835**	**6266**
2003	670	2506	3176	**1739**	**6038**	**7777**
2004	677	2798	3475	**1906**	**7449**	**9355**

Source: Graduate School Office of Tongji University

Fudan University Science Park

The university science park[11] concept was initiated in 2001 when 22 university science parks were approved jointly the Ministry of Education and the Ministry of Science and Education. Another 14 university parks were approved in 2003, and there are now altogether 36 such parks in China. Aside from Fudan Science Park there also exist science parks in another four universities – Shanghai University, Donghua University, Shanghai Jiaotong University and Tongji University. The main purpose of the university science parks is to support technology transfer and commercialize technologies – in close relation with universities. The Fudan University Science Park resembles Oxford Science Park in the UK, where private investment is also encouraged.

Fudan University Science Park (FUSP) is built in the surroundings of Fudan University and is located in the midst of one third of Shanghai universities and colleges, and surrounded by more than 100 research institutes. Its six main investors include Fudan University, a Shanghai investment company, the Technical Innovation Centre. None of the investors have a controlling power. The Park at an early stage attracted companies such as Fudan Microelectronics, Fudan Zhangjiang, Fudan Kingstar, Fudan Tianchen, and Fudan Biomedicine, and Fudan Water Engineering.

The university science park concept differs in several important ways from the high-technology parks that constitute an integral element of the Torch Program. First, the university parks attract smaller companies which are utilizing or developing novel technologies often in close collaboration with university departments. Second, university parks only have limited presence of foreign-invested companies and are less oriented towards export markets. However, there is frequent interaction between

[11] Information on Fudan Science Park is primarily based on interview with Mr Jia Wei, Deputy General Manager (January 11 2005) Shanghai Fudan Science Park brochure, undated

the research universities and their science parks on one hand and with the Zhangjiang High-Tech Park in Shanghai on the other. The university has established two related research institutions in Shanghai Zhangjiang Hi-Tech Park located in the Pudong area across the river:

1. Microelectronics Research Institute of Fudan University
2. National Microanalysis Research Centre of Fudan University

Yangpu district where the Fudan Science Park is located is a heavily developed part of Shanghai City. Consequently, the Park is not geographically concentrated but has its activities in different places around Fudan University. The present structure includes

- on-campus industrial research institute
- Handan Road Incubator Base Street
- Siping Road Headquarters
- Fenglin Road Campus, which is also the district of Shanghai medical university district
- Shanghai Qingpu Industrial Base
- Jiangsu Kunshan Industrial Base, actually located in a neighbouring province, to provide industrialization of products that have been developed with the Park

Most university science parks in China are managed by the universities themselves by providing capital and manpower. Fudan Science Park is different as Fudan University does not have the same controlling power as in other places. Fudan Science Park has from the very beginning been market-oriented with the objective of making profits and is paying annual dividends on investment. Fudan Science Park, as an organization, resembles a property development company that is looking for tenants that meet certain criteria. FUSP[12] is annually paying a dividend of 10 per cent on invested capital of RMB100 million. Shanghai Fudan Science Park Co, Ltd. is a sponsorship type equity limited company that was founded in September 2000 by joint investment from:

1. Fudan University
2. Shanghai Wujiachang Hi-tech Combined Development Company Ltd.
3. Shanghai Shangke Technical Investment Ltd.
4. Shanghai Lujiazui Finance and Trade Zone Development Ltd.
5. Shanghai Municipal Technical Venture Centre
6. Shanghai Yangpu Construction (Group) Ltd.

The development of Fudan Science Park is passing through several stages. In Phase I property development was carried out by a local construction company that in 2002 transferred the ownership to Fudan Science Park for the amount of RMB85 million. In Phase II the Park has bought land for expansion from the government at a cost of RMB300 million. During this phase a 24 storey building is constructed that will be completed before September 2005 when Fudan University officially celebrates its 100 Year Anniversary. Expansion is primarily financed by bank loans for which the Science Park pays an interest in the region of 5-6 per cent. When Phase III and Phase

[12] The management team includes specialists from finance and political circles, law, management and education. The President of the Board is Dr. Yang Yuliang who is Fudan university Vice-chancellor, also Special Professor of Ministry of Education “Changjiang” Project, and also Chief Scientist of Ministry of Science and technology 973 Key Fundamental Study Project.

IV are completed the Fudan Science Park will cover an area of totally 100,000 square meters

In early 2005 FUSP housed approximately 300 companies inside the Park, although only half of them have a direct relation to Fudan University. Anew high-rise building in Phase II can potentially house another 200 companies, although newcomers may be limited about 20 enterprises in order to provide expansion possibilities for already existing companies. Total employment of companies located within the Fudan Science Park is in the region of 3,000-5,000.

The Fudan Science Park, operating as a profit-making company has greatly benefited from the booming property market. Since its inception the property prices has risen from about RMB5,000 per square meter to presently more than 10,000, and it is expected that land prices will continue to rise. The company is responsible for management, providing services to tenants and making investments. These are focused on micro-electronics, biomedicine, new materials, information engineering, education industry and environment engineering. The Park has set up venture capital funds in collaboration with foreign companies such as the SK Group in Korea.

A high-tech company has several options for its location in Shanghai. Zhangjiang Hi-Tech Park is an obvious choice but threshold in terms of size and required investment is quite high. Furthermore all eleven of Shanghai's districts have also established their own industrial parks. Similar to Fudan another four major universities in Shanghai have also established science parks. It is relatively easy to be accepted in Fudan Science Park, without any requirement of being associated with the university as such, although it is emphasized that new companies should bring original technology. Furthermore, Fudan Science Park has also in the vicinity established its own Software Park – Fudan Fuhua (Fudan Forward) – which is already introduced on the stock market.

High Technology Parks

Zhangjiang Hi-Tech Park of is considered to be the most successful among the 53 national high-technology parks –arising from the Torch Program initiative. Preliminary statistics show that total revenues for 2004 reached RMB200 billion, with an exported value of US$10.3 billion. Shanghai has another four high-technology parks and altogether 28 incubators which are located throughout the city. A large number of the city's most important enterprises are located inside the Zhangjiang Hi-Tech Park, with many of them engaged in advanced knowledge creation.

The S&T Commission prepares annual plans which are directly related to the 5-Year Plan for Science and Technology, allowing adjustments for changing conditions and environment. Four regional park centres will play an important role in meeting the goals of these plans.

A substantial number of industrial parks and high-technology parks, often with attached incubator systems, play a very important role in Shanghai's industrialization efforts. Although the number of various parks is overwhelming, their structure and governance occasionally confusing, the following examples attempt to provide a

certain amount of clarification. Zhangjiang Park is located the Pudong area which is also the site for two large free trade and export processing zones. The other three technology zones mentioned below – Caohejing, Songjiang and Zizhu - are located in the old parts of Shanghai[13].

- Caohejing National Industrial Park (Caohejing Xinxin Jishu Kaifa Qu), that was established in the early 1980s, with a focus on information and industry, is the oldest high technology park in Shanghai. It is a technology development zone of importance for the nation as a whole, and the State Council has authorized the formation of bases for microelectronics, photo-electronics, computers, software and new materials – to support new major industries. By combining domestic advances with international exchanges the Park will develop into a High-Science and Technology Park along the Pujiang River The total number of companies is more than 1,700 which includes 450 foreign firms. Annual revenue has reached RMB40 billion
- Zizhu Science-Based Industrial Park (Minhang district) was established in 2001and will in its development combine three forces – private companies, institutions of higher learning and government agencies. It will rely on market forces and using educational and research resources to make Zichu into a modern science park With six leading sectors which include microelectronics technology, optoelectronics, digital technology, software technology, nano-technology and, and life sciences Zichu expects to attract high-tech enterprise headquarters, research and development centres, as well as venture capital companies.
- Songjiang Science & Technology Park (Songjiang district) was established in July 2002. Shanghai is in this most recent technology park striving to set up a third microelectronics industrial base after the Zhangjiang integrated-circuit (IC) industrial base and the Caohejing IC industrial base. This endeavour has been strongly supported by the Shanghai Semiconductor Industry Association that estimates that IC businesses in Shanghai will earn more than half of the total revenue for the sector in China. At present a number of foreign companies which include TCMC (Grace) from Taiwan well as domestic companies have decided to make total investment of US$1.15 billion for which construction has already started.

The Zhangjiang Hi-Tech Park

Zhangjiang Hi-Tech Park (SZHTP) was established in 1992, and has become well-known to foreign visitors. SZHTP had from the very beginning an ambition to learn

[13] Furthermore Shanghai also another four high-technology parks:

1. Jingqiao Modern Science and Technology park (Jingqiao Xiandai Keji Yunqu), with a focus on electronics was recently established. It has some 40 companies which are mostly foreign, including Bayer from Switzerland
2. University Science and Technology Park(s) System includes park at eight universities in Shanghai: Fudan, Jiaotong, Tongji, Shanghai, Donghua, Huagong Ligong, East China Normal, and "Maritime
3. Jiadoing Minying Science and Technology … … District (Jianding Ninying Keji … Qu) is a "returnee" park that was established in 2001 (?) and already has 500 companies of which 300 have been established by returning Chinese. Most other companies have a focus on energy and new materials
4. China Textile … … Science and Technology City (Zhongguo Fangzhi Guoji Keji Cheng) was established in the early 2000s and has a total of 145 companies.

from the Hsinchu Industrial Park on Taiwan. SZHTP in Shanghai and Zhongguancun High Technology Park in Beijing are generally seen as the two most successful examples of China's attempt to create this kind of institutional structures. In August 1999 Shanghai City government made a strategic decision to make Zhangjiang Hi-Tech Park into a focal centre for biological medicine, integrated circuits and software – as three leading industries. Within the ongoing 10th 5-Year Plan the area undertake the task to become the home for high technology and new technology industry as, and is expected by 2010 to have become a world-class high-technology park.

SZHTP is different from many of the other 53 hi-tech parks in China as the content/value of science is much higher here and the Park has attracted more foreign investment in R&D facilities than other locations. Furthermore, it has attracted Fudan University in Shanghai and many other advanced teaching/research institutions to set up branch campuses and there are now altogether more than 20 educational units[14].

Park officials argue that here is considerable interaction within the software and microelectronics fields and that SZHTP will by 2010 be of world class and compare favourably with Hsinchu and other similar sites around the world. The ambition has been to establish "innovation chains" in the three fields of semiconductor industry, software industry, biotech & pharmaceutical industry, and also provide support for SMEs through its incubator systems. In addition SZTHP also provides support for the bankcard and optical electronics industry.

A number of companies both domestic and foreign ones have been attracted to set up R&D centres within the Park. The largest single R&D unit within the SZHTP is operated by the Zhongxing Technologies (ZTE) Corporation with a total number of staff exceeding 3,000. Important national centres include:

1. Shanghai Super Computer Centre
2. National Light Source Project in Shanghai. This is a third-generation synchronous radiation device at the energy level of GeV with the objective to become a multi-discipline research centre to support industrial development of advanced materials and provide basis for a fundamental research in a wide array of knowledge fields.
3. Shanghai High Polymer Material R&D Centre. This is an open and new research institute involved in R&D and its commercialization in the area of high polymer materials.

The employment within the Park had by 2004 reached more than 40,000 of which ten per cent have Master degrees and another three per cent have doctoral degrees. Returnees have come to play an important role in further developments within the Park. According to incomplete statistics, there are about 3,500 returned overseas Chinese students having started business or working in the Park - with companies

[14] These include:

- Microelectronics Research Institute of Peking University
- Microelectronics Research Center of Tsinghua University
- National Software Institute of Fudan University
- Microelectronics Research Institute of Fudan University
- Information Security Engineering Institute of Jiaotong University
- Shanghai Research Institute of Xi'an Jiaotong University
- Shanghai R&D Center of University of Science and Technology of China

established by returned overseas Chinese students reaching close to 500[15]. Thus, Zhangjiang Hi-Tech Park has become an attractive choice for returnees.

The Zhangjiang Hi-Tech Park has its three technological focal points in three industries – semiconductors, software, and biotech & pharmaceuticals. This is reflect in the physical outlay of the Park and its further expansion and naturally reflected in the choice of companies invited or desiring to settle. The early choice of focusing on three sectors has also directed influenced the location of university branch campuses and the decision to local key technology centres or Key Research Facilities to the Park. The following will provide a short description of the character of the three focal areas and for each an example of major high-technology company that is active in the Park.

The semiconductor industry sector, and the SMIC foundry

Semiconductor Manufacturing International Corp. (SMIC) employs some 7,700 people of which 86 per cent work in China. 140 have PhD degrees and another 12 per cent have Master degrees with 31 per cent with bachelor degrees. Some 2,700 are contract workers. SMIC has a total employment of 6,626 in China with another 1,084 employees outside the country. SMIC does not have an expatriate system but supports education and provides accommodation. This has facilitated moving some 1,000 staff to China.

SMIC has training program in collaboration with three universities in Shanghai – Fudan University, Tongji University and Shanghai Jiaotong University. SMIC (in Shanghai only) has 600 R&D staff members in project(s) that were approved by the Ministry of Commerce in June 2004. SMIC has a number of IC foundry clusters in Shanghai, Beijing and Guangdong, and its foundries can produce chips with line width down to 0.13 micron. SMIC in 2005 starts mask making collaboration with Toppan in Japan, while chip packing is done in Chengdu.

SMIC is a unique implant in China being completely owned by foreign investors with Richard Chang playing a very important pioneer role. Huawei, ZTE and many other companies and other companies in China receive substantial planning support in China. SMIC people spent a lot of discussions with officials, before finally agreeing to establish its major semiconductor foundry operation in China. The company wanted to move a substantial number of overseas employees without giving them expatriate status. One challenge was that SMIC wanted to have its own school system and officials asked “why do you want to se up your own school?” However, eventually an agreement was reached on this and a number of other issues. After much persuasion Shanghai government provided substantial support and SMC Government Relations Team has turned out to be very important

SMIC provides one-stop solution for its customers from design to final testing and its business model is similar to that of TSMC in Taiwan. SMIC plants located in Shanghai, Beijing and Tianjin are pure-play foundries that offer 0.35-0.13 micron technologies for logic, mixed signal/RF, high-voltage circuits, memory, system-on-chip, and LCoS. Marketing and services are located in Milan, Tokyo, Fremont and Dallas. The main facilities in Shanghai also include mask making and testing. The

[15] Shanghai Zhangjiang Hi-Tech Park, Shanghai Zhangjiang Group Co., Ltd brochure, Shanghai 2004

newly created SMIC structure will in the future have several foundries all based on 12" wafers. During 2005 SMIC will enter into a joint venture with Toppan to manufacture on-chip colour filters and micro lenses, and another joint venture will be established in Chengdu for packaging and testing.

SMIC delivers various IC components for digital still cameras, HDTV, DVD players, smart pones and PDAs. SMIC has a strong R&D team with more than 700 specialists, and has established close partnerships with Toshiba, Fujitsu, Chartered, IMEC, Infineon, Elpida and Toppan. SMIC is delivering more and more high-end ICs. The share of ICs with a line-width of 0.18 micron has increase from 22 per cent of total sales in 2003 to 46 per cent during the third quarter of 2004.Logic wafer production constitutes majority of SMIC services. Partners include Elpida for DRAM down to 0.10 micron, and with Infineon down to 0.11 micron. SMIC has taken over Motorola IC production plant in Tianjin after discussions that started two years ago and were completed by January 1 2004.

SMIC identifies a number of cost advantages of operating in China which include the following ones. First, created cost advantages include water recycling and natural cooling. Second, lower utility costs with water fees being one third of those in Taiwan. Third, SMIC has access to large talent pool and lower labour costs by having access to engineering graduates from leading universities in China.

Shanghai is a major location for semiconductor foundries. China's IC manufacturing capacity is growing and there are presently 55 units in production. 38 units are working with wafer sizes of 3-5" and with line widths of more than one micron. China has presently 9 foundries that are using 8" wafers, with line widths in the region 0.35-0.11 micron of which four are operated by SMIC that also has built a 12" wafer unit in Beijing.

The ambition of Shanghai is that SZHTP Park should have 20 production lines of wafer production, and 20 enterprises in photo mask production, packaging and testing that would an expected output value of US$10 billion by 2010[16]. By March 2003 the Park industrial structure included 96 IC enterprise – 3 wafer fabs, 44 fabless units, 16 photo mask, packaging & testing enterprises, 10 R&D educational institutions and 23 vendors[17].

Software industry, and Zhongxing Technologies R&D Centre

The Shanghai R&D Centre of Zhongxing Technologies (ZTE) is located in the Innovation Zone of the Shanghai Zhangjiang Hi-tech Park. It is the largest R&D centre operated by hi-tech enterprise in Shanghai, with more than 3,000 research staff.

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[16] Shanghai Zhangjiang Hi-Tech Park Investment Guidebook

[17] IC companies within SZHTP include the following ones
Fabless: Infineon, ISSI, SST, Pixelworks, LSI Logic, Cadence, Synopsis, Sunplus, Via. Elan, Xirlink, Spreadtrum, SmartAsic, Huahong, Marvell, nVdia, Conexant, Onsemi
Foundry: SMIC, GSMC, HHNEC
Assembly: & Testing and Photomask: ASE, GAPT, STATS, Photronics, Ellepsis
Equipment vendor: Applied Materials, TEL, Novelius, ASML, Screen, LamResearch KLA-Tencor, TOWA, Praxair, Saes, Bolch
System application: Lenovo, Amoi, ZTE, Huahong, UTStarcom

Its work is focused on R&D for mobile systems of 2G, 2.5G and 3G, mobile handset and network products. ZTE operates its own “university”, located in Dameisha, Shenzhen, to provide training for international and domestic customers on technology, products and management.

ZTE, with headquarters in Shenzhen was established in 1985 and listed on the Shenzhen Stock Exchange in 1997. At the beginning ZTE was only a simple trading company and entered the telecom sector in the early 1990s when the domestic demand emerged and the company found that it had matching engineering competence in the field. ZTE has a total of 13 R&D centres of which are located in China. Shenzhen R&D centre is mainly involved in the development of CDMA systems, while also doing IC design, optical communication, teleconferencing systems, and power supply systems for telecom equipment. ZTE has three R&D centres in the US located in San Diego for CDMA2000, in Dallas for optical transmission and in New Jersey for soft-switches. The company also has a centre in Korea where development on handsets is carried out, and another small centre in Sweden. ZTE invests more than 10 per cent of annual revenue in R&D.

ZTE has worldwide employment of 19,500. This includes more than 500 PhDs and some 6000 Master degree holders. The share of bachelor degree holders is around 70 per cent.
Employees engaged in R&D 42 per cent of total ZTE workforce, with 19 per cent in production and 32 per cent in marketing.

The company has entered into agreements with a number of foreign companies. One important relation is with Motorola for joint development of ICs for speech digital signal processors. ZTE also maintains close relations with Intel and TI for other semiconductor categories. Another collaboration is with Agere in the development of 3G platforms.
ZTE also has established working relations with some 50 academic institutions, almost all of them in China. One important aspect of this network is to be able to identify and recruit talented engineers and scientists. Another very important element is joint research on frontline technologies such as 3G technology, optical communications, soft-switches and data communication.

ZTE is a global network solution provider and China’s largest listed telecom equipment manufacturer. The company has grown very rapidly in recent years. In 2003, sales revenue reached US$3 billion, an increase of some 50 per cent over 2002. During the first half year of 2004, ZTE achieved doubled its revenue over the same term of 2003. By the end of 2004 ZTE had deployed 35 million lines of GSM systems in 20 countries. ZTE is China’s largest CDMA equipment supplier in international markets, with 18 million lines of CDMA system adopted by over 30 countries. Contracted sales for 2003 in overseas markets reached US$610 million which is a year-on-year increase of 100%. ZTE recorded a very large expansion of its overseas sales during the first half of 2004. In 2004 ZTE raised capital on the Hong Kong Stock Exchange for its future expansion.

Pudong National Software Park is located within the Shanghai Zhangjiang Hi-Tech Park and has attracted a substantial number of companies, domestically and from

abroad. By the end of March 2003, more than 1,000 companies[18] hade been registered among which 228 had entered the Park by mid-2004[19]. Their total employment reached 7,000 and covers a number of fields such as system integration, e-commerce, chip design and information security. This group of enterprises include Microsoft.net, Citbank, Synopsis, Sony, BearingPoint, Kyocera, UnionPay, Kingdee, Tata, Infosys and Satyam.

The software industry in the Park also includes the China eastern 863 HiTech Information Security Base, with the following components.

- National Information Security Engineering Centre
- National Public Security Technology PKI Research centre
- National Computer Virus Technology Research centre
- Information Security Engineering Institute of Jiaotong University

A closely related activity is the Shanghai Bankcard Industry Park, with the stated objective to become the design and R&D centre for financial information products, and a data processing centre for financial organizations. The designated area comprises three square kilometres where the following companies will be present: China UnionPay, China Bank of Communication, Ping An Insurance Company and Bank of China.

Biotech and Pharmaceutical Industry, and ChemExplorer working for Lilly

Shanghai ChemExplorer Co., Ltd is one of the pharmaceutical companies within the Park structure that is promoted by the Zhangjiang Biotech & Pharmaceutical Base Development Co. Shanghai ChemExplorer started on a very small scale with only five people in July 2002. The company, doing contract research on organic compounds for Lilly in the US, was founded by Mr Hui who used to work (director?) for the Institute of Organic Chemistry in Shanghai that is under the leadership of the Chinese Academy of Sciences. After leaving the Academy institute Mr Hui served as Shanghai Vice-Minister for Science and Technology before he founded ChemExplorer. ChemExplorer can only carry out R&D activities which are directly related to the interests of Lilly. Mr Michael is managing director.

ChemExplorer works exclusively for Lilly and has concentrated its research in three areas of which one is identification of active substances in the screening of natural samples. Every two weeks meetings are held with Lilly counterparts. Lilly has a number of that (research) sites in a number of places in China – Hangzhou, Qingdao, Shenzhen, Dalian and Shanghai. After its early start ChemExplorer has expanded rapidly to presently some 200 people of whom 15 per cent have Master degrees and another 15 per cent have Doctor Degrees. Location in the Park has a number of advantages. First, an environment for pharmaceutical research has been created within the Park, to which the presence of the Shanghai College of Traditional Chinese Medicine (TCM) has contributed. Second local government support has also been important.

[18] Shanghai Zangjiang Hi-Tech Park Investment Guidebook
[19] Shanghai Zhangjiang Hi-Tech Park, Shanghai Zhangjiang Group Co., Ltd brochure, Shanghai 2004

The company expects to recruit 20-30 more staff members during 2005. Talented people are sought from other places and the company has been on recruitment missions to Hangzhou, Nanjing, Dalian and Tianjin, an activity which is also boosting the image of the company. The company will increasingly look for qualified people

The aim of Zhangjiang Hi-Tech Park in the biotech and pharmaceutical industry is to create a cluster of activities that will provide the platform for industrial development in biotechnology and traditional Chinese medicine as well as new drugs and medical devices. To support its objective a specialized development company was created in 1996 - Zhangjiang Biotech & Pharmaceutical Base Development Co., Ltd. – established jointly by the Ministry of Science and Technology, Ministry of Health, the Chinese Academy of Sciences, State Food & Drug Administration, and Shanghai Municipal Government.

ZZHTP aims to attract recognized pharmaceutical companies from overseas and from China, and expand the R&D structure and improve its contents by attracting talents. More than 120 small and medium sized companies have already been established in the Park, which also hosts the Shuguang Hospital and the Shanghai University of Traditional Chinese Medicine. Research activities include the following:

- Shanghai Institute of Materia Medica (CAS)
- National Human Genome Centre at Shanghai National Centre of Drug Screening
- National Centre for New Drug Safety Evaluation & Research
- National Centre for TCM Innovation
- National BioChip Engineering Research Centre

Foreign pharmaceutical companies with presence in the Park include Roche, Amersham, GlaxoSmithKline, Boehringer Ingelheim, Kirin, Sankyo, Tsumura and Medtronic. The domestic ones include Pioneer, Greenvalley, Celsar, Sanjiu, Tasly and Taiji. A number of them, including Roche and Dupont have substantial R&D presence in the Park. DuPont of the US started in late 2003 to build its China Corporate Research and Development Centre in the Zhangjiang High-Tech Park with a planned investment of RMB124 million. The centre eventually accommodate up to 200 scientists and focus on technical marketing, with the aim of localizing the production of existing products in the Asia-Pacific market. The R&D centre will open in early 2005 and will become DuPont's third comprehensive R&D facility outside the United States, the other two being in Europe and Japan.[20].

Conclusion

Huge amounts of innovations - of a gradual and incremental nature - are taking place in manufacturing firms all over China, although primarily in the dynamically evolving coastal areas. These firms have often agglomerated into geographical clusters and are found in many industrial sectors. A number of clusters are evolving into centres of strong innovative capability. They are still weakly linked and inadequately supported by actors within the state-level innovation systems.

[20]China Daily, 5 November 2003. More recent information suggests that Dupont is making more significant investment on R&D facilities within the park, amounting to US$100 million, and will employ 250 people.

However, a natural formation of three major regions in China have prompted provinces and cities within them to act as midwifes to bring out an environment that can deliver not only incremental innovations but also breakthrough innovations in future-oriented industries. A number of regional development programs and projects play an important role in this process and has the potential of enhancing needed and strong links between clusters, foreign technology sources and national programs. Shanghai has naturally come to play a dominant role in the Yangtze River Delta (YRD) region, surrounded by dynamic cities such as Ningbo to the South and Hangzhou, Wuxi and Suzhou further inland. Simultaneously, increasingly close industrial and technological relations with Taiwan have boosted Shanghai's knowledge potential.

This report which is based on interviews and visits in Shanghai carried out in early 2005 indicates that China is on the verge of establishing innovative knowledge regions where Shanghai and Beijing are in the forefront. Although this development is guided from above and with substantial local or national budget resources it is strongly supported by local initiatives and entrepreneurship. This dynamic character is likely to be duplicated in many other locations in China. The regions and their clusters are now playing a significant role and their embedded innovation systems might greatly contribute to China becoming a technological superpower.