The Evolution of China's Software Industry

By

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1. Introduction

China's policies to reform the S&T system during the last two decades have increasingly focused on the promotion of high technology industries. The ambition has clearly been to catch up with advanced industrialized countries through a combination of technology import, international cooperation and joint ventures, as well as support for indigenous development of new technology. The emergence of new technology-based entrepreneurial firms in the late 1980s, and the rapid growth of several of these firms during the 1990s, bears witness to the new capabilities that have been created in the process. Information and communication technology (ICT) has been a key area of focus in the drive to modernize the economy and to create new industrial and service sectors in China – epitomized in the ambition to develop a new knowledge-based economy (Dahlman and Aubert, 2001). The development of the Chinese software industry has been one important component of these attempts to modernize China's economy and create an indigenous capability for technological innovation in the 21st Century.

Given a rapid growth of markets for software products and services in China during the last decade, there is now a great potential for further development of the Chinese software industry – including a significant growth of indigenous software firms. The value of output from the Chinese software industry grew from 4.4 billion yuan in 1992 to a total of 110 billion yean in 2002, with an annual growth rate of 38% - or four times the growth rate of China's GDP (Xinwen jujiao..., 2003). Table 1 shows the growth of output value for software products, services and exports during 1999-2002. It is worth noting that the rate of growth of software product markets is greater than that of software services, and now constitute more than half of the domestic market sales. Exports were still a small component of the output in the late 1990s, but are growing at a rapid rate. The total value of software production in 2002 was equivalent to 37.9% of the total value of the market for computers in China – up from a comparative proportion of 25.6% in 1999 (CSIA, 2003). Recent statistics suggest that China boasts around 8,500 software firms with 18,000 registered products (China's software…", 2004)

Table 1: Revenues of China's Software Industry, 1999-2002 (billion RMB yuan; annual growth rate in square brackets)

	Software Products	Software Services	Software Exports	Total
1999	18.2	23.9	2.1	44.1
2000	23.8 [30.8%]	32.2 [35.0%]	3.3 [57.0%]	59.3 [34.3%]
2001	33.0 [38.6%]	40.6 [26.0%]	6.0 [80.0%]	79.6 [34.2%]
2002	50.7 [53.8%]	46.9 [15.5%]	12.4 [106.7%]	110.0 [38.2%]
2003	103.7 [104.5%]*	53.8 [14.7%]*		
2004	140.0 [35%]*	70.0 [30%]*		

Source: 1999-2002: CSIA, *Zhongguo ruanjian chanye fazhan yanjiu baogao (2002-2003 niandu) [Annual Report of China Software Industry],* p. 77

* Estimates based on "2004 nian zhongguo ruanjian shichang xiaokoue yuji chang da dao 2100 yi renminbi" *Beijing xiandai shangbao* 25 February 2004 (accessed trough China Infobank)

The growth and structure of the Chinese software industry has been analysed by several international scholars. Saxenian (2003) focuses on the role of the incomplete institutional transition from a planned to a market economy and, in particular, the role of personalized social networks in shaping the development of the market for software in China. Her analysis also highlights interesting issues of human resource development, such as the role of brain drain, and problems of ownership, access to capital, and management structures. In her view, the immature state of the Chinese software industry and the influence of government and personalized relationships will remain major obstacles for the future development of the industry – especially considering the potential impacts of China's entry into the WTO. In contrast, Tschang and Xue (2003) argue that the Chinese software industry shared some characteristics with the emerging success of Chinese electronics industry and that rapid growth of the domestic market had fostered some strong firms. A strategy oriented primarily towards the domestic market represents a very different approach compared with countries like India and Ireland, but this strategy provided new opportunities for the software firms to integrate with various forms of knowledge systems and develop new products and capabilities in competition with multinational firms. The prospects of China becoming a new center for international software production also indicate a potential rivalry between China and India in the international software markets, but the strengths and weaknesses of each country suggest complementarities and thus great potential for co-operation (Tschang, 2003).

The Chinese government has become increasingly aware of the importance of software in the development of the information technology industry and ultimately in economic growth. As will be further discussed below, Chinese S&T policies have provided support for high priority software research and development for decades, but promotion of the growth of software firms intensified in the 1990s, and policy support for the software industry as such culminated in the Circular of the State Council on "Some Policies on the Encouragement of Software and IC Industries" issued in 2000 – often referred to as circular 2000 no. 18 (Guowuyuan, 2000). More recently, the high priority attached to the further development of software has been underscored by the "Programme of Action for Promotion of the Software Industry" for 2002-05 issued by the General Office of the

State Council – referred to as document 2002 no. 47 (Guowuyuan bangongting, 2002). These policy measures indicate a high level of ambition in terms of creating a viable domestic software production base and more extensive exports of software services.

Given the growth that the Chinese software industry has experienced in recent years, and the importance that the Chinese government increasingly attaches to the development of the industry, one is tempted to see China as major growth pole for future software development in the Asia-Pacific region. At the same time, the reforms of the S&T system have led to new opportunities for high technology entrepreneurship, and many new spin-off firms from research organizations or universities have entered into software production. The apparent success of China in creating a domestic computer industry, expanding the telecommunications sector, and developing an export base for consumer products such as DVD players, suggests that a strategy based on imports of key foreign technology and indigenous S&T development and commercialization in rapidly expanding, competitive markets might also work for software.

However, the specific characteristics of the Chinese software industry encourage a more cautious assessment of its future role in global markets. Even the hitherto impressive growth of domestic software firms in the rapidly expanding Chinese market may be threatened by the expanded presence of foreign vendors as a consequence of China's WTO entry. In other words, the future of China's software industry is contingent on a wide range of factors and involves many uncertainties. The present paper does not seek to cover all these factors, but seeks to explore the role of the Chinese innovation system and China's S&T policies in the evolution of China's software industry. The analysis presented here seeks to show that the evolution of the software industry reflects many of the key issues in the reform of S&T in China, including dilemmas regarding the role of policy instruments and market forces, the position of foreign technology suppliers and the creation of domestic technological capabilities, or the impact of globalization on China's economy. It will be argued that, from its early beginnings, the development of software and computer services in China has been shaped by the structural and institutional characteristics of China's innovation system, and that the development trajectories of the

industry and its key agents therefore have been significantly influenced by the national and local contexts that economic institutions and policy frameworks have provided.

The paper will be organized as follows: First, we shall briefly discuss some theoretical perspectives relevant for the analysis of the development of software industries, including the co-evolution of markets and institutions under the influence of national innovation systems and policies. Second, a review of the historical development of the industry is presented. Third, the paper discusses some key characteristics of the current status of producers and markets. In conclusion, the paper will analyse the extent to which the Chinese experience in the development of software reflects the impact of S&T policy reforms and the changes in China's innovation system.

2. Analytical Perspectives on the Evolution of Software Industries

The software industry is usually defined as covering organizations engaged in sales of computer software or services related to computer systems. For instance, OECD statistics broadly defines software industries in terms of data for ISIC Rev.3 division 72, which includes activities related to the design, setup, operation and maintenance of computer systems and networks, as well as custom software development and software publishing (OECD, 1998; see also OECD, 2002). Private sources of statistics on the software sector often takes its point of departure in the products and markets, and thus include packaged software, custom software, and computer-related services such as system design, maintenance. While custom software has been produced since the early days of computer use, and remains a very important activity internally in firms, packaged software has become a very important segment of the market during the last decade and now constitutes a key area of competition among industrialized nations (OECD, 2002). The relative competitive strength of various countries in producing packaged software and custom software or services also reveals the influence of important institutional features of major markets such as the US and Europe (Mowery, 1999).

An important element of understanding the evolution of software industries is to adopt an historical perspective, and study how the interaction of actors, institutions, markets and policies shape the development trajectories of software in various phases of their development. The evolution of the software industry in industrialized countries has been outlined in terms of four eras by Mowery (1999). The first era (1945-65) was characterized by the emergence of standard operating systems and application programs for mainframe computers like IBM 360. During this period, most software was produced by computer manufacturers and users and written for bespoke applications. The second era (1965-78) witnessed the entry of independent software vendors, due to the "unbundling" of software products from hardware sales. Much of the traded software was still developed for specific mainframe computer applications, and competence built up by mainframe computer users started to support the marketing of applications. In the third era (1978-93), the diffusion of the microcomputer created a large market for packaged software and the emergence of "dominant designs". Decline in the cost of computing technology also opened up opportunities for independent software vendors in what turned out to be mass market for software during the 1980s. The fourth era in the development of the software industry (1994-99) has been dominated by the growth of networking among computers, both as local area networks and via the Internet. This has opened up new markets for software and encouraged the emergence of new "dominant designs" and applications that operate on several platforms, potentially undermining the positions of major software vendors.

Mowery shows that the US software industry has maintained a competitive advantage globally throughout these four eras – although with different firms dominant and successful in various eras. The evolution of computer software industries in the US, Japan and Western Europe reflects the co-evolution of markets and institutions in each region. Relevant factors included the structure and role of central government policies toward the industry; the relationship between competitive strength in computer hardware and software in the evolution of the software industry; and the importance and characteristics of user-producer relationships in software. Many of these themes are rooted in the contrasting structures of the national innovation systems of the competing

economies, while others are more specific to the sectoral innovation system for the software industry (Mowery, 1999: 155). In other words, international comparative studies of software industry suggest that the characteristics of national innovation systems are crucially important for their evolution.

At the same time, the evolution of software industries has been influenced by some distinctive features of software development and marketing. One feature noted by many authors is that software is developed with large fixed cost while distribution is influenced by its public good character, necessitating various forms of appropriability regimes (legal protection, lock-in with standards) in order to achieve economies of scale in marketing (Torrisi, 1998: 39-40; von Daalen, 2001). Another feature has been the complementarity between hardware and software, which has caused software to adapt to innovations in hardware and have provided externalities for software producers interacting with leading hardware manufacturers. The need for interoperability between hardware and software has also stimulated the development of de facto standards, such as the "open-but-owned" systems based on Intel and Microsoft products – which in turn have become the core of a new business strategy aptly dubbed Wintelism (Borrus and Zysman, 1998). Moreover, a major characteristic of software production is the extreme importance of skilled human resources, which is reinforced by the craft-like, creative processes of "informational" production based on tacit, knowledge-based system. This has implied that the dominant pattern in the evolution of software industries has been extensive growth through new sources of skilled labor. Such growth promotes the agglomeration of production in specific regions within specific firms, with global migration flows fueling production growth (Eichen, 2002). In short, the knowledge-intensive features of software industries has tended to generate patterns of development that encourage vertical integration and concentration in dominant places or firms on the one hand, but also a fragmentation of the industry, depending on domain-specific knowledge, on the other hand.

In a global perspective, the advanced industrialized countries – in particular, the US – maintain a very strong position based on dominant technology and property rights. For developing countries that are latecomers in software production, a number of specific

issues emerge with any attempt to develop local capabilities and innovative domestic software industries. Successful followers such as India and Ireland have specialized in providing service to overseas customers on the basis of low cost advantages in the provision of skilled labor, without much innovative work and with a limited extent of horizontal linkages to the domestic economy. Compared with the dynamic cluster of software industries in the Silicon Valley, the clusters that have emerged in India and Ireland generally lack innovative capabilities and are dependent on established markets overseas (Arora et al., 2001). Nevertheless, an early success which is based on a narrow range of activities may lead to future growth involving more innovation as technological capabilities are accumulated. Other countries such as South Korea and Taiwan have sought to mobilize domestic software firms on the basis of growing national and international markets and thus reduce the relative dependence on global vendors of software. National markets are particularly important for indigenous development of software service firms which may capitalize on knowledge related to specific conditions in the local economy or domain.

Although the literature on the development of software industries is in its initial stage and is based primarily on the experience of the US and European markets, there appears to be an emerging consensus that the formation and structure of software industries in a country emerges through the co-evolution of markets, actor strategies and institutions in a process that is shaped by the following factors:

- Interaction and technological capabilities of key actors, including producers of hardware and software, users of software and researchers
- Size and growth of markets, both for domestic and overseas users, and the level of competition between domestic and foreign vendors on these markets
- Institutional frameworks at the national as well as the global level, including the protection of intellectual property rights, the adoption of standardized and interoperable systems, and relevant incentives for competition and cooperation
- Policies affecting the software sector, including the relative priority on hardware vs. software, the training and mobility of skilled manpower, large-scale R&D projects, and regulation of competition and property right protection

3. The Historical Evolution of China's Software Industry

This section will provide an overview of the main eras of the evolution of the Chinese software industry, starting with the state-sponsored initiatives for software development in the 1970s and ending with the most recent era of rapid growth of firms exploiting markets generated by the Internet boom and "informatization" of the Chinese administration and economy. We shall end the section with a profile of the structure of the Chinese software industry that has come about as a result.

The Era of Bundled Software Development

The development of Chinese software followed a trajectory that lagged years behind software development in the West. In particular, the first era of software bundled with mainframe or minicomputers continued to characterize software development in China until the 1980s. The first impetus for creation of a genuine software industry came during the third era in the 1980s, when the diffusion of the desktop computer in China introduced a need to develop operating systems and packaged software with Chinese language processing capabilities, building on research efforts launched after a major conference in August 1974 identified Chinese language processing as a key priority (Lan, 2000). However, most producers of software during the early 1980s were government operated research institutes, while spin-off firms from these research organizations were only gradually emerging. A significant impetus for new software development came from major research projects launched under the Sixth Five-Year Plan (1980-85) and, in particular, as part of the Baliusan (863) high technology plan. The domestic demand for software was still dominated by customized systems for mainframe and minicomputers, often for industrial applications, while the market for general purpose software products was constrained by the inadequate framework for legal protection of software (Baark, 1990).

In significant ways, the evolution of software production in China in the era of bundled software until the middle of the 1980s was dominated by a few key characteristics of the traditional innovation system. Software production was primarily regarded as a research activity that was concentrated in the Chinese Academy of Sciences and research institutes under the various sectoral ministries. Priorities for new software development were determined administratively under the planning process, and appear to have been dominated by the demands of key economic sectors and defense. Although software received more attention from policy makers in the 1980s, this activity did not gain a fraction of the resources set aside for the electronic industry in general, and there was no recognition of the need for extensive training of software engineers, support for application of software in society, or an independent software industry as such. Software R&D began to be concentrated in areas that would have a key impact on the future of the industry, such as Chinese language processing (which ultimately became the basis of successful companies like Founder), but there were as yet no concept of mass markets for software products, and in addition to basic software research most actors were engaged in the development of bespoke applications. Most software was being generated in a few geographical locations with advanced research institutes such as Beijing and Shenyang.

The Era of Microcomputer Systems

A major milestone for Chinese software development during the 1980s was the creation of Chinese language platforms for popular microcomputer operating systems such as the CC-DOS system written by Yan Yuanchao in 1983. This program was available free of charge to the public and quickly became widely used, while other improved versions such as UCDOS soon entered the market (Lan, 2000: 30-36). The next major step forward in providing Chinese language operating system was the Chinese Star "Zhongwen de xing 1.0" system for Windows written by a bright young engineer Wang Zhidong in 1991, which became the core of the very successful RichWin system that Wang Zhidong developed for the Stone Computer Corporation (Lan, 2000: 38-39). Moreover, Chinese software enterprises have invested considerable resources in developing an indigenous operating systems, including the COSIX system based on UNIX that has been developed

by the China National Computer Software and Technology Service Corporation (CS&S) since the early 1990s, and a range of Linux systems such as the Red Flag Linux system developed in the late 1990s (Lan, 2000: 42-63).

The era of microcomputer systems in the 1980s coincided with the transitional reform stage of the Chinese NIS evolution and provided a vital impetus for the establishment of software firms. On the one hand, the changes that took place in the system of management of research organizations provided new avenues and incentives for entrepreneurial scientists and engineers to try to exploit their knowledge of computers and software in the market. On the other hand, the new markets for PCs and associated software products created by economic and administrative reform gave the entrepreneurs greater opportunity for developing new spin-off firms and to sustain growth through the early stages of development. Good examples of software firms that emerged as spin-off from universities include Founder Group (*Fangzheng*) established 1986 by Beijing University, which has become the leading provider of typesetting and publishing software for publications in Chinese (Lu, 2000), and the Top Group which was created in 1992 by professors from Sichuan University - Top being a pun on "Three old professors" – and which aims to become a leading provider of administrative software services in China. Most major software firms in China have been established by entrepreneurial people from research institutes or universities. Indeed, research in the Chinese Academy of Sciences and at universities was crucial for the development of software in China during this period, and constitutes the origin of a large number of software firms (Tschang and Xue, 2003). However, UFSoft (*Yongyou ruanjian* "User's friend software") was established by two professionals, Wang Wenjing and Su Qiqiang, who both had a strong background in accounting and software development and who had previously worked for the State Council (Lan, 2000). This company has been very successful in developing and marketing accounting and financial software for Chinese firms, but in contrast to many of the spin-off enterprises it initially drew heavily on domain knowledge rather than research results.

The emerging software industry remained geographical concentrated to a few locations. Beijing was an important center for the establishment of new software firms, many of which continue to dominate the industry today. Another up-and-coming center that began to become significant was Shenzhen, where companies like Huawei and Kingdee were established during the 1980s. Other important industrial centers such as Shanghai and Tianjin also witnessed a growing software production, although this process was influenced by foreign investments – such as the case of the Motorola.

The Era of IT Systems Diffusion

While the 1980s witnessed the birth of high-tech IT firms serving a new mass market in China, much of the industry was still dominated by assembly of microcomputers and software that was bundled with the computer sales. Independent software vendors were rare and enterprises that were providing computer and software services such as the China National Computer Software and Technology Service Corporation (CS&S) were essentially state-operated units serving both the government and the market. During the 1990s, however, the production of computers in China grew explosively and a wide range of organizations installed computerized systems for financial or administrative purposes. This diffusion of IT hardware in Chinese society created a fertile ground for the establishment of independent firms that would provide specialized software and services. The expansion of the telecommunications sector, including the rollout of many new systems for mobile telephony, provided another opportunity for domestic vendors with a technological strength in software development to capitalize on the emerging markets. This was clearly the case for the HJD-04 public digital switching system developed by the Zhengzhou Institute of Information Engineering which is discussed in Shen (1999); another good example is Huawei Technologies, which has one of the largest internal software research units among private Chinese firms. At the same time, the institutional environment for creation of high technology ventures was becoming increasingly supportive, with initiatives such as the establishment of High and New Technology Industry Parks and the Torch Program setting up incubation centers, together with many schemes set up by local governments, giving a sense of encouragement that had not

hitherto been available. However, the market for software was still heavily influenced by attitudes of users and government authorities that still had little appreciation for intangible products – with widespread illegal copying and marketing of software which received little protection yet from legal authorities. In the context of this situation, customized software and services (including services bundled with IT sales) were probably easier to sell with a reasonable return, which in turn led to the predominance of services based on expanding domain expertise such as administrative programs for specific sectors of the Chinese economy (telecommunications, financial sector, energy, education…), or various forms of system integration. Moreover, most Chinese organizations lacked knowledge about IT applications, and therefore successful firms would normally provide extensive training and customization services with sales of software and hardware.

This era of IT diffusion served important purposes in terms of providing a potentially large and growing market for software producers that became the fertile breeding ground for many of the independent software vendors that currently rank among the largest in China. Although Chinese software engineers in state run research institutes and corporations continued to play a vital role in the development of new programs and systems, the initiative appeared increasingly to shift to software engineers employed in high technology firms with some form of private ownership – regardless of the fact that due to the improved mobility of talented people many of these engineers had come to the new high technology firms from research organizations or universities. One of the key initiatives of S&T policy reform, namely the establishment and expansion of high technology parks in China during the 1990s, also helped many software firms through the early stages of growth and ensured them of a favorable business environment in places like Beijing (Segal, 2003). The progress of reforms in the science and technology system was accompanied with extensive opening of the Chinese coastal economy to foreign direct investment and management during the 1990s, which generated opportunities for emerging software producers in China to import foreign technology (Baark and Heeks, 1999) but also gave them a new sense of competition from established software vendors.

The reform of institutions such as property rights and ownership of firms gave organizations producing software new prospects for expanding their operations. The introduction of stock markets in China, for instance, enabled a few companies like the Shenyang-based NEU Soft (formerly Neu-Alpine Software co. *Dongda erpai*) to raise new capital for expansion through listing on the Shanghai Stock Exchange in 1996. There were increased efforts – especially on part of foreign vendors – to crack down on software piracy in China, but the legal framework and implementation continued to be inadequate. Interestingly, the diffusion of software through illegal copying might paradoxically have helped Microsoft gain its dominance in the Chinese market through network effects (Williams, 2002).

During the era of widespread IT diffusion, there were a number of new locations like Shandong province and Xi'an that started to witness the growth of local software industries, but the geographical concentration continued in central locations such as Beijing and Shenzhen. Some of the large software firms also expanded their network of branch offices, but the market for software in China remained fragmented.

The Era of the Internet and Informatization

There is no doubt, however, that the latest era of networking and extensive computerization of administrative tasks in Chinese public and private organizations has provided a key driving force for the current and future growth of the Chinese software industry. This process – usually dubbed *xinxihua* [Informatization] in China – has been further fuelled by a number of policies promulgated by the Chinese Government. The need for China to enhance its process of modernization in ways that would bring about a new "Knowledge Society" has been extensively discussed in China and has attracted the attention of foreign observers (Dahlman and Aubert, 2001). The Internet craze that swept over China during the end of the 1990s resulted in a boom of internet service providers (ISP) and content providers (ICP) that emerged by the thousands (Wong and Ling, 2000). Although political priorities have dictated rather cumbersome gateways to the global internet for Chinese users, the popularity of Internet access and some of the leading

websites in China such as Sohu.com have persisted despite the dotcom crash that hit China in 2001. The political and economic ramifications of the Internet in China are significant, but beyond the scope of the present paper (see Hughes and Wacker, 2003).

A distinguishing feature of this era of software development in China is the new and extensive role of government sponsored projects in fuelling the market. During the early 1990s, several "Golden Projects" were launched for the development of advanced information networks such as the Golden Bridge for exchange of economic data, the Golden Card project aiming at the provision of a secure network for credit cards, and the Golden Customs Project with a network for foreign trade. These procurement projects sought both to support the domestic software industry and simultaneously to enhance key economic sectors such as finance and economic planning. More recently, a series of e-government projects have been initiated by national as well as local agencies (CSIA, 2003, p. 224) that will lead to the establishment of more extensive networks in a wide range of sectors. They are also followed by government-initiated enterprise on-line projects that will install web facilities in a large number of state-owned or –controlled enterprises in China. Promoting e-commerce and e-citizenry in China, these rather grandiose projects are also intended to capitalize on the recently expanded telecommunications network and familiarize Chinese organizations and citizens with computerized transactions (Lovelock and Ure, 2002).

The procurement of software by Chinese government organizations has also sparked controversy in foreign relations, however. For instance, the Beijing Government chose local firm Red Flag Linux over Microsoft as supplier for its office products, and a subsequent adoption of a State Council decision in August 2003 to require domestically produced software in all government ministries during the next cycle of software upgrades (Suttmeier, 2003). This decision led to protests from the US Information Technology Association of America, and may prompt further complaints to WTO. Nevertheless, the Chinese government remains concerned about the monopoly position of major foreign software vendors, which is seen as a problem for the emerging domestic

software producers as well as a serious issue related to sensitive security concerns in China.

The Chinese government has also intensified its direct support for software industry, for example, by encouraging the establishment of software parks (*ruanjian yuan*) or software bases (*ruanjian jidi*) in major Chinese cities. Statistics from 30 of these software parks and bases indicate that firms in these earned a total revenue of 95 billion RMB yuan (CSIA, 2003, p. 127). The efforts to build infrastructure for software production has been supplemented with facilities for training of software engineers and technicians, and several software parks have been set up or managed by firms, such as the parks established by the Top Group. After the first wave of proliferation of software park initiatives, there has been an effort from the government to encourage more advanced facilities, and 22 parks have been certified nationally by the Torch Program. Still, a large number of local software park initiatives are in existence, and a critical debate on the rationale and sustainability of software park schemes has emerged (see "Ruanjian jidi…, 2002).

An interesting development that has taken place since the mid-1990s is foreign investment in R&D facilities in China. Some of the early entrants in the Chinese market like Motorola have expanded their R&D facilities and created a number of centers in key locations in China. More recently, major vendors like Oracle have also expanded and upgraded their R&D facilities in China. But perhaps the most noteworthy move came when Microsoft set up Microsoft Research-Asia to undertake basic and advanced applied research in Beijing. The establishment of the research lab followed several unfortunate incidents during the 1990s, such as the revelation that the phrase "Communist Bandits (*gongfei*)," which is a term common to Nationalist KMT propaganda in Taiwan, appeared to be utilized in Windows 95 installation kits sold in China, several lawsuits against

copyright infringement that provided an negative image of a foreign bully or "wolf" practicing hegemony, and a failed launch of the Venus internet TV in 1998.[1]

The creation of the Microsoft Research lab in Beijing with more than 150 researchers and a substantial budget in many ways served to improve the negative image that had been created by these incidents, but has also succeeded in attracting well-known scientists and engineers from the US to manage project groups which consisted primarily of talented engineers from the PRC Mainland. In accordance with the original mission laid out for Microsoft Research network, MSR-Asia has primarily pursued basic research and its researchers have succeeded in publishing articles in scholarly journals. They have also been engaged in applied research projects such as the Digital Ink technology developed for Tablet PCs.

Microsoft Research-Asia is, however, rather unique among foreign R&D labs in China, since it has continued to devote most of its ample resources to basic research while many other multinational software producers operating in China, such as IBM, have gradually turned towards applied research and development. It is also noteworthy that it has been able to build and maintain a status as a "Center of Excellence" in the global network of Microsoft Research. Finally, MSR-Asia has demonstrated how important the access to talented human resources in the knowledge-intensive environment of Zhongguancun in Beijing is for potential software developers.

4. The Current Structure of the Software Industry and Markets

This section will discuss key aspects of the current structure of China's software industry, the domestic markets, and exports. The discussion cannot be exhaustive, but serves to indicate features that are relevant for evaluating the aspects of the national innovation system that have shaped the evolution of the industry.

[1] This analysis of Microsoft builds upon a manuscript by Yun-Chung Chen entitled "Microsoft Global Innovation Networks – the Role of MSR-Asia in Beijing", March 2004. I am grateful to Dr. Chen for sharing his work with me.

Industry structure

Given the rapid growth of the markets for software products and services in China since the late 1990s and the policies introduced since 2000, there has been a very high rate of growth in new entrants into the industry while, at the same time, a group of Chinese software firms with established reputation have become relatively large. Thus, domestic Chinese software and systems integration firms with an annual income in 2002 of more than 500 million RMB Yuan represented 0.8 per cent of all firms in the sector, while those with an annual revenue less than 10 million RMB Yuan constituted 75 per cent. Nevertheless, the proportion of software and systems integration firms that earned a revenue larger than 10 million RMB Yuan in 2002 formed almost 25 per cent of firms in the sector, a clear improvement compared to 2001, as shown in Table 3. A small group of 19 firms had revenues exceeding 1 billion RMB Yuan in 2002 , but only 0.5 per cent of the software firms had more than 1000 employees and 94 per cent had less than 200 employees (CSIA, 2003: p. 96-97). In other words, although a group of Chinese domestic software firms had become reasonably large, the majority are very small. Although some specialized small new ventures may have a considerable competence and may be expected to expand their capabilities quickly in growing domestic markets (Tschang and Xue, 2003: p. 31) many observers have lamented the weak technological status and capabilities of the greater part of small software firms in China.

Table 3: Proportion of Various Sizes of Chinese Software and Systems (As percentage of total firms based on annual revenue)

Annual revenue Year	More than 500 million RMB Yuan	100-500 million RMB Yuan	10-100 million RMB Yuan	Less than 10 million RMB Yuan
2001	0.4%	2.1%	9.5%	88%
2002	0.8%	3.5%	20.7%	75%

Source: CSIA, 2003, Table 1-21, p. 97

The problems related to the limited capabilities of the vast population of relatively small Chinese software firms, which primarily rely on craft-based approaches to software development, is compounded by the fact that they often compete in a few popular domains with virtually identical products. The industry thus appears ill prepared for competition with large foreign software vendors, once these enter the most popular market segments such as ERP or network management with more mature and sophisticated products and services that have been localized for the Chinese context.

Software producers in China nevertheless include a group of fairly large companies. In Table 4, the 15 largest software producers in China are listed, indicated their main products and services together with the annual revenues earned in 2002. Although the statistical figures presented in this list may be inaccurate, since the precise accounting for software revenues are difficult, the table nevertheless indicates that telecommunications firms are dominating the sector, reflecting the role of the market for digital communications and wireless switching system in China during the last decade. System integration services are also important sources of revenue for many firms. Dedicated software firms like Microsoft (China), NEU-Soft and UFSoft only represent a minority of the largest companies.

Table 4: The Fifteen Largest Software Development Firms in China, 2002 (Annual Revenue, Million RMB Yuan)

Firm Name/ Location of Headquarters	Major Products or Services	Software and computer services revenue		
			Software revenues	Services revenues
Huawei Technologies/ Shenzhen	Telecommunications	6,040	6,040	
ZTE (Shenzhen Zhongxing Telecom)/Shenzhen	Telecommunications	3,786	3,546	240
Putian Eastcom Telecom/Hangzhou	Telecommunications	2,432	2,432	
Digital China/ Beijing	Systems integration, ERP	2,321	525	1,796
Beijing Ericsson Mobile Telecom/Beijing	Telecommunications	2,089	2,089	
Beijing Beida Founder Group/ Beijing	Publishing, systems integration	1,556	1,556	
Microsoft (China)/Beijing	Operating systems, Office and Server Applications	1,464	1,464	
NEU-Soft/ Shenyang	Accounting, security, systems integration	1,421	654	768
China National Computer Software and Services Corp. (CS&S)/ Beijing	Systems integration, ERP, e-Government	1,329	512	490
Datang Telecom Technology Group/Beijing	Telecommunications, Systems integration	1,283	103	1,181
Langchao Group/Jinan	Power sector, transportation, Telecommunications	1,254	504	751
Tsinghua Tongfang/Beijing	Systems integration	1,080	159	888
Yantai Dongfang Electronic and Communication/Yantai	Systems integration	940	337	604
Shandong CVIC SE/Jinan	Systems integration Finance, Middleware	920	328	592
UFSoft/ Beijing	Accounting, ERP software	852	834	

Source: Based on the list of 100 top software firms in China at website http://www.csia.org.cn/info/2002softwareTOP100.htm (accessed March 2004)

In short, China's software industry exhibits a high concentration with a group of large firms producing software for telecommunications and another group offering systems integration dominating the sector. Few of the dedicated domestic software firms have reached a level of revenue that includes them among the 50 largest producers.

Table 5: The Largest 30 Software Firms in China, 2003

Rank in 2003	**Name of Firm**
1	Huawei Technologies Ltd.
2	ZTE Shenzhen Zhongxin Telecom Ltd.
3	Top Group S&T Development Ltd.
4	Digital China (Shenzhou Shuma) (China) Ltd.
5	Langchao Group Ltd.
6	Shanghai Siemens Mobile Communications Ltd.
7	Panda Electronics Group Ltd.
8	NEU-Soft Group Ltd.
9	Beijing Beida Founder Group Co.
10	Microsoft (China) Ltd.
11	Tsinghua Tongfang Ltd.
12	Datang Telecom S&T Ltd. (Beijing)
13	CS&S China National Computer Software and Services Co.
14	Air China Information Network Ltd.
15	China Great Wall Computer Group Co.
16	CVIC Software Engineering Ltd.
17	Zarva (Chaohua keji) Group Ltd. (Chongqing)
18	Beijing Ericsson Mobile Telecom Co.
19	Shanghai Alcatel-Bell Mobile Telecom Systems Co.
20	Beijing Tianqiao Beida Jade Bird S&T Co.
21	Beijing Oracle Software Systems Co.
22	Yantai Dongfang Electronics Information Industry Group
23	Shanghai Baosight Software Ltd
24	Zhuzhou Time (Shidai) Group Co.
25	Beijing UFSoft Ltd.
26	HiSense Group Ltd (Shandong)
27	Yunnan Nantian Electronics and Telecom Industry Co.
28	Kingdee Software (China) Ltd.
29	Nanjing Nari-Relays Group Co.
30	Hunan Changsha Newsky S&T Development Co.

Source: Based on data provided by the Ministry of Information Industry in "2003 nian zhongguo ruanjian chanye zui da guimo qian 100 jia qiye" http://www.csia.org.cn/info/2003softwareTOP100.htm (accessed March 2004)

In terms of ownership patterns, the software industry is dominated by more than half of the firms operating under a limited liability registration and twenty per cent under private ownership, while state ownership remains a small minority. Around fifteen per cent is under foreign ownership, as shown in table 5.

Table 5: Patterns of Registered Ownership in China's Software Industry

Limited Liability Companies	Privately Operated Firms	Firms with Foreign Investment	Share-Holding Companies	Firms with Investment from HK, Macao and Taiwan	State-Owned Enterprises	Others
51.4%	20.0%	10.5%	8.0%	4.3%	2.7%	4.0%

Source: CSIA, 2003, Table 1-13, p. 86

The emergence and rapid growth of the software industry in the last decade has clearly been happening under a new institutional regime which encourages entrepreneurship. Indeed, the growth and dynamism of the sector reflects new approaches to management and ownership patterns that are increasingly gaining ground in the Chinese economy.

Location of Major Software Industries

The early development of China's software industry was concentrated in a relatively small number of localities, with Beijing, Shenzhen and Shanghai as the dominant sites of new firms. However, software research took place in a variety of institutes or universities in other localities in China, and since new software firms have often emerged as spin-off from these types of organizations, the geographical concentration of the Chinese software industry to a few locations is now less prominent. The successes of companies like NEU-Soft based in Shenyang and the Top Group based in Chengdu indicate that there are ample possibilities for agglomeration of software talent outside the main centers in the coastal areas of China. Nevertheless, as Table 3 indicates, in terms of overall size of

software industries and output in various categories, Beijing and Shenzhen are still occupying major shares of software revenue in China.

Table 6: Software Revenue in Various Localities in China, 2002 (Billion RMB Yuan)

Locality	Type of Software Activity				
	Software products	Software services and systems integration	Embedded software	Software exports*	Total software revenue
Beijing	9.55	22.74	2.00	220	36.11
Shenzhen	4.15	4.00	8.50	400	19.97
Guangdong	5.60	4.13	2.26	270	14.20
Shanghai	3.25	6.42	0.58	175	11.70
Zhejiang	6.76	4.02	0.05	20	11.00
Liaoning	2.88	4.10	0.07	80	7.60
Jiangsu	3.04	3.73	0.56	20	7.50
Shandong	4.80	2.05	0.33	7	7.23

Source: CSIA, 2003, Table 1-11, p. 85

Note: * Million US dollars

Nevertheless, Beijing with its Zhongguancun "Silicon Valley" district remains dominant, particularly in sales of software and system integration services. Guangdong and Shenzhen are very important centers for embedded software and software exports. The table also shows that although Shanghai remains one of the advanced centers for high technology industries in China, and in spite of the ambitious goals that the Shanghai government has pursued in promoting software industries, the Shanghai region has not yet been able to overtake Beijing and Guangdong/Shenzhen.

Beijing and Shenzhen also have the largest workforce employed in software industries (91,882 and 70,000 respectively), with more than double the number of people employed in these industries in Shanghai, Guangdong, Zhejiang or Shandong. Significantly, both Beijing and Shenzhen boast around 12,000 software researchers, with the other four localities having from around 1600 to 4300 researchers each (CSIA, 2003, p. 98). While these numbers for the geographical concentration of software human resources may change as other localities train more people, the agglomeration effects of the current

concentration is likely to continue for some time. Statistics available for R&D expenditure in the software industries reveal a slightly different pattern of concentration. The three top spending localities are Beijing (2.17 billion yuan), Shenzhen (4.15 billion yuan), and Shanghai (2.12 billion yuan), with most other software centers spending significantly less than 1 billion yuan. The importance of Shenzhen in terms of R&D expenditure is significant and may be related to the existence of research-intensive telecommunication software industries and outsourcing of R&D from Hong Kong.

The importance of Beijing as a geographical center for software industries is most likely the result of three factors: first, the concentration of research organizations and universities in Beijing that have ensured a steady supply of skilled personnel; second, the early experience of "plunging into the sea" (*xiahai*) entrepreneurship by scientists and engineers from research institutes and universities, and the particularly favorable policies adopted by the local government (Segal, 2003); third, the continued importance of the central government organizations for research funding and as a market for software and services. Shenzhen's supremacy as a geographical center is also associated with its early status as a venue for entrepreneurial talent but, in addition, a highly significant factor is foreign investment and relocation of software development to Shenzhen from both domestic high-tech enterprises and overseas (particularly Hong Kong and Taiwan) firms. The profiles of Beijing and Shenzhen reveal the significance of the research infrastructure and the entrepreneurship unleashed by reforms of the S&T sector as a basis for the development of the software sector. In addition, both localities have benefited from foreign investment and international linkages – which have been critically important in the case of Shenzhen.

Software Manpower

The software industry in China employed approximately 550,000 professionals in 2002. Around 300,000 of these professionals were engaged in R&D or programming in software firms. In addition, an estimated 450,000 people were engaged in research, teaching, or applications related to software in a range of other industries or organizations

in society (CSIA, 2003: p. 99). Employment in the sector has grown rapidly during the last five years, commensurate with the expansion of software firms, as shown in the table below.

Table 7: Employment of Specialist Software Professionals in China, 1998-2002

Year	No. of Specialist Professionals Employed	Annual Growth Rate of Employment
1998	132,000	-
1999	150,000	13.6%
2000	186,000	24.0%
2001	250,000	34.4%
2002	300,000	20.0%

Source: CSIA, 2003, Table 1-24 and 1-26, p. 99 and 103.

China has also taken initiatives to train more software engineers, programmers, and other professionals in related fields such as information science, geographical information systems (GIS), automation, network engineering, etc. The 248,603 registered graduates that had completed software related education in 2002 included 336 people (0.14%) with a PhD degree, 3491 people (1.4%) with a Masters degree, plus 91,666 persons (36.9%) with a regular undergraduate degree and 153,110 persons (61.56%) with a degree from vocational training institutes (CSIS, 2003, p. 103). The various higher education institutions play a major role in training people for the software industry.

The importance of research organizations and universities as breeding ground for software entrepreneurs is revealed in statistics pertaining to the background of employees in software industries surveyed in 2002. As much as 71 per cent of employees have entered software firms from universities or research organizations, while 17 per cent came from various vocational training institutes or on-the-job training programs. The remaining 12 per cent were students who had returned from overseas (CSIA, 2003, p. 152-153). This latter category represents the crucially important “brain circulation”

identified by Saxenian (2003), and has recently been recognized as vital to new entrepreneurship in software parks and high tech zones in China.

The reliance on institutes of higher education and research organization for training of software manpower could be a problem in the long run, since the projected human resource requirements of the software industry in general shows that there is a gap between supply and demand of approximately 20,000 people annually, which are unlikely to be supplied by universities and colleges. Various projections show that as many as 600,000 software professionals – or more than double the current number of employees – will be needed in China by 2005 ("Acute Shortage…", 2003). Most of the major universities, including general universities such as Beijing University, Tsinghua University, Nanjing University, are currently recruiting around 800 students in software related subjects every year (CSIA, 2003, p. 161), and the rate of growth that can be feasible for this type of education is limited. Moreover, the actual demand for skills may not be oriented towards people with higher education degrees

Thus, the fact that around 77 per cent of software professionals are graduates from university and college education indicates an important structural problem in the system of training for software professionals. Compared with other software producers such as India, China has lacked training schemes for basic level technicians and there has been a tendency to employ people with relatively high levels of education for basic programming tasks in many Chinese software firms; according to one source, 16 per cent of software engineers engaged in elementary programming had a PhD degree ("Acute Shortage…", 2003). Accordingly, several initiatives are being implemented to boost the short-term training of software professionals, including collaboration with Indian and US training institutes and universities (CSIA, 2003, p. 163-166). The Jade Bird Group associated with the Beijing University has set up a joint venture with India Aptech Co. to provide diploma courses and degrees for more than 22,000 people at 76 training centres in various cities in China. Moreover, major software firms in China have launched large-scale training facilities to meet the requirements from their own business, as well as the other software producers in China; for example, the Top Group has established eight

information technology colleges in software parks in China. It is expected that the expansion of private training facilities for programmers will help China achieve a more balanced framework for development of software manpower, and at the same time support the expansion of manpower resources as the domestic industry matures.

At the same time, the Chinese software industry has suffered from a shortage of personnel with training and experience in management of development projects, systems analysis and specification, and other advanced software development skills. Currently, many people receive such skills while working for foreign-owned software firms or joint ventures; the technological spill-over that occurs with mobility of human resources between foreign and domestic firms is one element of the Chinese strategy to upgrade its software sector. Nevertheless, problems have also appeared because the location of software industries is not fully aligned with availability of manpower, and the mobility of trained software engineers remains constrained by institutional and regulatory frameworks. For example the year 2002 witnessed a glut of software manpower in Beijing, caused in part by the dot-com crisis that shook Zhongguancun and in part by the fact that software professionals from all over China tend to congregate in Beijing, while other localities still had short supply of manpower (CSIA, 2003, p. 150).

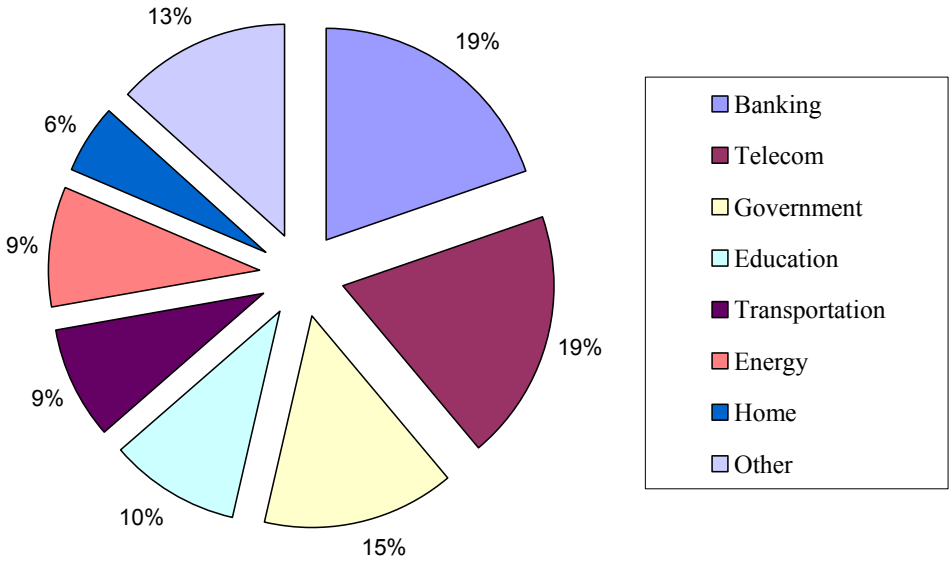
Markets

The revenue of domestic market for software in 2002 has been estimated at 97.7 billion yuan. Around 48 per cent of this market derived from sales of software services, while 52 per cent came from sales of software products (CSIA, 2003, p. 79). During most of the 1990s, many firms earned more selling services than products, partly on account of the high rate of piracy for products. Another important reason for the recent growth of revenues from software products is the introduction of embedded software products, which now constitutes 12 per cent of software products sold in China. The increase in revenue from embedded software products is especially important for telecommunications equipment producers such as Huawei, ZTE and Putian Eastcom, which now earn 20-35 per cent of their revenue from embedded software (CSIA, 2003, p. 79). Applications occupies the major part of software products (64.8%), with smaller

shares of supporting software (21.8%) and systems software (13.4%); similar proportions pertain to software services, which are also dominated by applications software. Services such as systems integration has been a crucial component of the information technology market in China, and this type of service is still very important, partly on account of the low level of IT systems users. Moreover, many software products are still sold with extensive packages of training, customization, maintenance, etc..

The major markets for application software products are related to specific domain applications (20 billion yuan), while the market for applications used across sectors (9.6 billion yuan) is dominated by standard management software (such as ERP, CAD and GIS), with financial software and office packages taking up smaller markets. The market for general-purpose software (3.2 billion yuan) includes three major categories: network software (0.87 billion yuan), security and anti-virus software (0.9 billion yuan), and computer games (1.2 billion yuan).

Figure 1: Major Domain Markets for Software in China, 2002



Source: Zhonghua renmin gongheguo xinxi chanye bu ed. (2002), p. 167.

Compared with world packaged software markets reported in OECD (2002), it is clear that systems software constitutes a smaller proportion in China (13.4% in China versus 32% in the world). However, this discrepancy may be influenced by bias in Chinese statistical data which may not cover systems software sold together with IT hardware and definitely does not include sales of pirated systems software. Moreover, software development tools such as database management systems, that occupy almost 20% of world markets, have yet to become a major market in China. The market for database management systems, for instance, is currently estimated at 3.8 billion yuan – or approximately 4% of the domestic software market in China (CSIA, 2003, p. 367). Foreign suppliers have at least 90% of this market, and in spite of the importance attached by the Chinese government to the development of local systems for strategic reasons (including extensive research funding as part of the 863 high technology component of the 10th five-year plan), it has been difficult for Chinese firms such as Neusoft with its OpenBASE system to capture a substantial part of the market.

On the other hand, domestic producers have captured major shares of software markets related to management and administration in Chinese organizations. The two leading domestic providers of enterprise resource planning (ERP) systems in China, UFSoft and Kingdee, supplied approximately 32% of the 1.6 billion yuan market in 2002, while international vendors SAP and Oracle together provided less than 20%. For accounting and financial systems, the domestic producer's share is even larger, but also fragmented with many small software firms and regional specialization (CSIA, 2003, p. 377-382). The large share captured by domestic producers is related to the unique accounting practices and management standards adopted in China that have required considerable customization of foreign systems. In fact, one report has argued that Chinese approaches to ERP differs significantly from those current in the West, with a preference for partial or gradual implementation instead of tightened integration of data related to financial, manufacturing and human resource requirements and processes ("Chinese Hi-tech Manufacturers", 2001).

It is expected that this market will receive a further boost from the Chinese government's "Informatization" initiative that will upgrade information systems in many public agencies and key state-owned corporations. This will certainly provide new opportunities for domestic vendors, but given the increased importance of international standards that will follow China's entry into WTO, the burgeoning market for management systems in China may also offer more scope for foreign vendors.

Exports

Software exports have grown rapidly, but still constitute only a relatively small share (11.2%) of the total software production in China. Compared with Ireland (12.7 billion US dollars) and India (9.9 billion US dollars), the Chinese software exports (1.5 billion US dollars) remain small. Most of the Chinese software exports in 2002 have gone to Japan (60%) and other South East Asian countries (21%). The US market (12%) and Europe (6%) have become more important destinations for software exports recently (CSIA, 2003, p. 106-107).

The reason for most exports going to Japan is the similarity in cultural background, the use of double byte coding for characters, and traditional business ties, particularly in the Northeastern provinces of China. Dalian and Shenyang have developed several firms with strong export orientation towards the Japanese market. One of the leading Chinese software firms, NEU-Soft in Shenyang, survived during the early years on the basis of outsourcing contracts for Japanese clients, which in 1991 constituted two-thirds of the company's revenue. Later, the company entered into a joint venture with the Japanese auto-electronics firm Alpine. However, since the firm achieved a successful expansion on the domestic Chinese market in the late 1990s, exports only provided ten per cent of its revenue in 2000 (Kroeber, 2001). Japan remains a major software outsourcing market for Chinese firms, however, and export of software services to Japanese clients has grown rapidly in Beijing, making the city another important center for software exports ("Japan becomes…", 2003).

Shenzhen is also a leading center for software exports, capitalizing to a considerable extent on its geographical proximity to Hong Kong and relationship with Taiwanese producers. Shanghai has formulated aggressive plans to attract foreign clients and investments in its software industry, setting up extensive facilities in the Pudong Software Park; nevertheless, software exports only accounted for less than 9 per cent of the production value of software industry in Shanghai. Critics have argued that the lack of interest in developing overseas markets, lack of skilled software project managers, lack of innovative products, and especially lack of internationally acknowledged certification for quality of management and products – such as license under the Capability Maturity Model, CMM – is holding back the export potential of Shanghai firms (Zou Huilin, 2002). The lure of the domestic market is also strong, and indeed, a firm like Shanghai Huateng Software Systems that was established in a joint venture with US-based Tandem Computers and which did a great deal of outsourcing in the early 1990s, has now abandoned much of its export work to focus on more lucrative domestic markets in the financial sector (Kroeber, 2001)

At the same time, it is clear that much of the exports hitherto have been based on labor cost considerations and to some degree also on Chinese language capabilities of programmers. Given the manpower shortages that continue to characterize the Chinese software industry, it is also unlikely that China will be able to emulate the Indian success in entering and expanding in overseas markets. A recent evaluation of offshore markets stress that the cost advantage of outsourcing to China is high, given IT salaries in the range of US$3000-8000 and access to highly competent university graduates. However, it states that "Software companies are in China now, not because of labor quality but because it is a buyer's market. Simpler work that can be done in India can also be done in China, but scalability and value chain growth will take time." (neoIT, 2003). For more advanced and reliable services, most international clients will still turn to Indian suppliers.

Intellectual property rights

Perhaps the single most controversial issue for software vendors in China is the rampant copying that takes place in many Chinese cities. The Business Software Alliance (BSA) estimates that the rate of software piracy has witnessed a modest drop from 97 per cent in 1994 to 92 per cent in 2002. Based on this rate, the BSA estimates that US$ 2.4 billion were lost in retail revenue due to piracy, representing 44 per cent of revenue lost in the Asia-Pacific region and 18 per cent of total dollar losses for software industries on a world scale (Eight Annual Software…, 2003). The foreign vendors have consistently complained about the widespread nature of illegal copying of software products in China, but Chinese software companies have increasingly joined the chorus (Enterprises in East China…, 2003). In December 2001, one of the leading Chinese software firms Beida Founder won a lawsuit brought against two Beijing companies that had installed Founder's software in their typesetting equipment, and was awarded 600,000 RMB Yuan in compensation.

Observers attribute the widespread disregard of intellectual property rights to culture: a long historical tradition of learning by copying, and emulation of classical works. It is also emphasized that the price differential between legal software and pirated copies in many developing countries, including China, put legitimate copies out of the reach of many consumers. However, the ease of access to pirated copies of software programs in China is also a result of the poor implementation of existing laws and the fact that some of the firms that thrive on production of pirated software are protected by local government officials. With China's accession to WTO, the expectation has been that protection of intellectual property rights, and particularly software products, will be improved. Nevertheless, the surveys conducted by BSA only shows marginal improvement, and it has been difficult to break the ingrained institutions of the society tacitly providing acceptance of copyright infringement which are embedded in both Chinese culture and social norms.

There is, however, no doubt that the widespread existence of software piracy in China has shaped the development of the Chinese software industry decisively. For many years, software firms have been forced to bundle software with hardware or with services in

order to expand markets and maintain profit rates. The importance of systems integration or embedded software in the business portfolio of most major software firms bears witness to this tendency.

5. Conclusions

This evolution of the Chinese software industry can be analyzed in terms of the history of its development and the characteristics of its current status. These features of the industry – acquired over several decades of development – are important to consider when assessing the future position of the Chinese software industry and its role in the global networks of software development and applications. They are also crucial to consider when comparing the Chinese experience with that of India or other emerging software centers. We shall briefly review these features before entering into a discussion of the potential future prospects for the Chinese software industry.

One of the important changes that have taken place in China during recent decades is the broadening of actors involved in innovation and their role in the development of new products and services. In the traditional Soviet system, state-owned and controlled research institutes dominated the process; gradually, various forms of spin-off firms and other enterprises have become more important. The software industry has drawn extensively on this process, with the majority of firms originating in research organizations and universities. The research orientation is still very strong among Chinese software firms, and some actors still adhere to the belief that technical sophistication is the core of competitiveness, in spite of the fact that successful firms are those that have responded well to market signals.

The policy adopted initially in the 1970s and 1980s for support to software development was extremely narrow, focusing exclusively on priority research projects. Throughout the three last decades of the century Chinese policy makers were focusing on hardware rather than software. For this reason, the commercialization of software was not a serious priority, and the needs for a good institutional environment (such as protection of

copyright) or adequate financial resources for the emerging software producers was largely ignored – despite extensive rhetorical statements. On the other hand, the emphasis on hardware production and technology transfer in the IT industry has provided a significant impetus to software production in areas such as telecommunication and embedded software. The potential for additional interaction between software and hardware in the Chinese industrial system is a distinguishing feature that may prove beneficial in the long run.

In adequate access to financial resources has remained a serious constraint for the development of the industry. While funding through major state-sponsored research projects under the five-year plans and the 863 high technology plan has been important for the development of key software programs, these resources did not help much in the commercialization phase. It has been crucial for the industry that spin-off firms were able to accumulate their own funds through sales of IT hardware and services during the early part of their growth. In other words, retained profits from sales to rapidly growing hardware or service markets became a major source of finance during the reform period. In recent years, stock markets and venture capital funds have also supplemented these sources of finance. Nevertheless, many Chinese software firms continue to be constrained by the difficulties of raising adequate financial resources from conventional sources such as banks. Lack of funding for expansion plans have also served to retain a very large, and even growing, body of small firms which operate under workshop management and which cannot undertake large and complex projects for domestic or foreign clients.

The human resources for software industry in China have primarily relied on research institutes and universities. However, in the rapid expansion of the industry and for the future, it is unlikely that universities or other higher education institutes will be able to provide sufficient numbers of well-trained software engineers, or indeed the right kind of software professionals for the industry. The rapid expansion of training opportunities in programs run by domestic schools – often with foreign curriculum and/or instructors – promises to improve the skill levels of the many technicians that are required for

expansion of the software sector. Returned overseas students have come to provide a new and entrepreneurial component of the human resources in software.

The problem of software piracy probably biased many Chinese software producers towards bundling of hardware and services with software development. Although the problem has abated somewhat with stricter control of intellectual property rights, the consequences of piracy still appear to cripple domestic producers of software as much as – if not more than – foreign software vendors. The Chinese government has undertaken new policies that seek to provide better incentives and environments for the growth of the industry, such as software zones. However, the importance of rapid IT diffusion in Chinese society should not be overlooked, as the markets for software has grown rapidly in connection with the spread of microcomputers and mobile phones. The Chinese government has also utilized public procurement policies and its current campaign for the "Informatization" of the Chinese society to generate important new markets for the domestic software industry.

Exports of software products and services by Chinese firms have not attained anything like the growth rates witnessed in India, Ireland or Israel. One problem is the lack of experience in international markets and the absence of established procedures and reputation for quality control (such as that provided by the CMM certification). Another problem is that the attraction of the rapidly growing domestic market diverts attention of many Chinese software firms away from foreign markets or outsourcing opportunities. In both of these respects, India has achieved a much more successful record of outward orientation. It is interesting to note, however, that the complementarities between Chinese and Indian IT and software industries are becoming more apparent than the actual points of competition. Already now the Chinese telecommunications and software firm Huawei has established an R&D division in Bangalore in order to exploit the higher level of Indian skills in project management. Several Indian firms such as the large software firm Infosys have entered the Chinese market, while Indian providers of network software have teamed up with Chinese hardware firms to supply integrated solutions. In fact, the analysis carried out by Li and Gao (2003) suggests that as a latecomer, China may not be

able to pursue the strategy that provided India with a strong foothold in the US outsourcing market, and instead should build alliances and cooperation with foreign software superpowers (such as India) to pursue a path of balanced development.

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