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The Chinese Software Industry: A Strategy of Creating Products for the Domestic Market

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1. Introduction

This paper examines China's software industry, which though is only a recent phenomena, has often been compared to that of India's, and is considered by observers in India and elsewhere to be possibly a prospective threat to India's software export services[2], and even an opportunity for India. Although China's hardware manufacturing industry is better known in the world, software has become an official part of the strategy for new industrial development. The Chinese software sector will have plenty of interesting implications for the alternative paths to development that may be considered by other countries.

There are a number of peculiarities to China's software industry which suggests that it may be quite different from India's, in particular, it has somewhat different beginnings, and a distinct structure and role in the economy quite different from India's mainly export-driven software industry. Consequently, a large part of China's industry could follow a different path from India's. Whereas India's domestic products market is dominated by (mostly Western) multinationals, China's domestic firms hold about 33% of the market, with official policy being to increase this to 60% in 10 years (Gartner, 2002).[3]

The strength of the Chinese software industry comes in part from the huge market of users and domestic producers, and this is fueling the needs for software of all kinds, including products. There is conventional belief in industry watchers and government alike that the industry is largely made up of smaller, weaker firms, and that there is a need to grow larger firms. Part of this perceived weakness comes from the process capabilities, which are believed to be poorer than India's. Poor software process capabilities were cited by Huawei, a large Chinese telecoms firm, as a reason why it located a major software development facility in Bangalore, India (interview with Huawei, 2001). Rampant software piracy and high employee turnover could also be two factors that contribute to the smaller and weaker size of China's software firms.

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[2] NASSCOM presentation materials, 2002.

On the other hand, there is the perception that China's software industry is benefiting from its hardware industry, namely, that the need of domestic manufacturers for embedded software will provide advantages to the domestic software producers. This point has been discussed previously by others who believed that one strategy for growth would be to focus on producing software for the domestic sector (Heeks, 1999). This path had been followed by Brazil some time ago (Schware, 1992), which had a relatively stronger domestic industrial position not unlike China's.

Currently, the software industry is already a fairly large proportion of the overall computer industry, as shown in the table below, but is still a very small proportion of the country's GDP.

Table 1. Output of software, computer industry and total GDP (100 million yuan)

	Output of software industry	Output of computer industry	Software as proportion of computer industry	Total GDP	Software as proportion of GDP
1999	441.5	1720	25.6%	82000	0.54%
2000	593	2150	27.6%	89000	0.67%
Growth rate	34%	25%	-	8.5%	-

However, the growth rate of China's software sector is still far below that of India's, which suggests that a different growth path is at work, e.g. that firms have a weaker set of capabilities (and therefore may be unable to attract business), or that a domestic growth strategy has idiosyncracies unlike that facing India's export sector.

In light of these issues, this paper will examine the growth and current status of the Chinese software industry. First, it provides an overview of the origins and structure of the industry. Then, using primary data we have collected at the firm level, we will examine the status of the industry. This will allow a comparison of China's software industry with that of India's.

Specifically, we would like to address the following questions:

- What are the origins of the industry and what is its basic structure?
- Is the conventional belief that the firms are smaller and weaker true?
- Are perceived problems with the lack of process capabilities, piracy, and human resource turnover a problem for the industry?
- In what ways does the domestic-led focus help software firms, and in particular, how do domestic firms form competitive advantages? To what extent does this make a unique "Chinese model" that is different from India's?

To address these questions, we will use interview data collected from semi-structured interviews with a variety of sources, including about 30 Chinese software companies and several government officials, including officials from 3 regional software parks and the Ministry of Science and Technology (MOST). We also used secondary data from industrial and government sources.[4] The study selected four main cities and their software districts of parks: Beijing, Xian, Shanghai and Jinan.

[4] The interview format partly shared some elements in common with a similar study done previously on India

In the following section, we will sketch a broad outline of the Chinese software industry's current status. We will follow this with a discussion of our dataset in section 3, which will be analyzed in sections 4 and 5.

2. Current Status of China's Software Industry

The Chinese software industry appears to be moving forward on many fronts. However, in our account, we pay particular attention to the main difference between China and India, which is the strong dominant product focus of the Chinese industry (as opposed to providing contract services, which is the mainstay of India's industry).[5]

Some aspects of the Chinese economy are expected to have positive influences on the industry's growth, such as the strong manufacturing sector, which uses software in many products even beyond computer equipment, e.g. telecommunications equipment (some of which is now 50% software), consumer electronic products, automated machinery. There are about 20 million small to medium sized enterprises in China, which provides a substantial business user base. This base is expected to increase the domestic software market from 10 billion to 100 billion in 5 to 8 years (CSIA, 2000)[6].

Furthermore, the proportion of the population with personal computers is ever increasing, reaching nearly 29 million on shipments in 2000, and the proportion of mobile telephone users has rapidly increased, reaching 145 million telephone users in 2000, of which 85.2 million were mobile users (Tan and Wu, 2002, citing various sources)[7]. This PC market was so large that it could comfortably sustain the expansion of a number of domestic manufacturers, with six of the largest vendors being Legend (9.1% of the PC market revenue, based on revenue of 271 million US for 235,535 shipments), Tonru (4.9%), Founder (2.9%), Great Wall (2.2), and Langchao (1.2%) (Stone was also amongst the largest, but not tracked for this period) (Gartner, 1998). The low costs of Chinese PCs have caused US, Japanese and even Taiwanese manufacturers to either lose market share or be forced into local joint venture operations.

Although the proportion of this user base is still small and has been said to be holding back e-commerce, there appears to be enough critical mass of business and household users to also sustain a viable population of software firms. The question is whether this population of firms (or some subset of it) will continue to concentrate as fewer and fewer firms, or is sufficiently sustained by the growth in the user base to continue growing individually, or if they will continue to be small and weak because of some internal dynamic, e.g. a continuing drive to hypercompetitive low costs and quality.

Since China is a huge country with a diverse software industry, there are a number of dimensions relevant to understanding the industry. We will review some of the available industry data in order to capture the following dimensions:

- The regional distribution and their character
- The main activities, e.g. services, products, and exports

[5] The Indian industry does have a domestic products segment and increasing numbers of product spinoffs, albeit one that is still a proportionately far smaller portion of its industry as compared to China's proportion.

[6] Gartner estimates about 6.8 million SMEs, defined as companies with anywhere from 1 to 500 employees (Gartner, 2001).

[7] This is based on shipments of 7.4 million units in 2001 for China, vs. about 1.8 million for India. Nevetherless,

· The human resources situation

We will also identify some of the main industrial and product sectors in the following section. Given that a significant number of the better firms are product-focused, the Chinese software industry can be divided into different categories depending on the characteristics of the sector they serve.

Although the role of multinationals should not be marginalized, thus far in our interviews, it appears that multinationals have not had such a great impact on the firms, either in terms of employee experience or training, or by being clients for the firms. The biggest impact appears to be in terms of competition at the high end of products and services, with multinationals having secured about two thirds of the domestic product market.

Industrial Structure and Characteristics

The values and growth rates of different sectors are shown in the table below. The services component is the largest in total sales, services being a combination of systems integration, outsourcing services and other activities (e.g. maintenance). Exports are much lower but are increasing rapidly year over year.

The proportion of China's software industry's output that is export-based is only about 5.6% in 2000, versus about 70% (i.e. exports of 4 billion out of 5.7 billion USD) for India in 1998 (NASSCOM, 1999). As noted earlier, the percentage of China's industry that is product-based is also quite high, accounting for about one third of the total in 2000.

Table 2. The industry breakdown by major sector: sales (100 million yuan [about 12.5 million US dollars]) and growth rate (source: CSIA p.2)

	Software products	Services	Exports	Total
1999	182	238.5	21	441.5
2000	238	322	33	593
Rate of growth	30.77%	35%	57%	34.3%

In 2000, of the total products sales of 23.8 billion yuan shown in the table, packaged software products are about 1.5 billion yuan. But in fact, this number is underestimated because it only represents some of the direct sales, and is estimated to be about 10-15% of actual total.[8] Of this packaged software, about 65% of the sales (1.27 billion yuan) come from application products, 21% from supporting software and 14% from system software. So in fact, software products could likely be an even greater proportion of the software industry in China.

The rate of growth of total software sales was 330% in 1992[9], but fell to a more modest rate of 34.3% by 2000 (the latter is shown in table 2). This contrasts with the Indian software industry's higher compounded annual growth rate of 59% between 1998-1999. This may not be so surprising, given that China's industrial and personal demand for software did not have

[8] The software products numbers are based on direct sales from retailers who only sell computer software. This excludes bookshops, supermarkets, and other outlets, in addition to original software loaded onto manufacturers' machines.

[9] This number is calculated from data, but the large rate could be an artifact of data-related issues, such as

a strong external impetus like the US demand for software, especially during the Y2K boom leading up to 2000.

Table 3. Growth in sales of types of products for selected years (100,000 yuan) (source: CSIA, p. 5)

	1992	1996	2000
System software	1.6	8.5	33.2
Supporting software	5.4	20.0	49.6
Application software	12.8	63.5	155
Total	19.8	92	238
Rate of growth	330%	35%	31%

Human Resources

The table below shows that the total number of graduates in computer related fields and workers in the software industry is steadily growing. Other estimates put the pool of IT professionals at about 150,000 in China for 2001, versus about 522,000 in India, based on graduates of 50,000 and 73,218 per year respectively, and a total demand of 350,000 and 400,000 respectively. Like India, China also suffers an outward migration of graduates to the US (Gartner, 2002).

In recognition of the slow growth rate, the national and local governments are instituting wider plans, such as the designation of 35 universities nation-wide as national software engineering programs. Cities like Shanghai and Jinan are actively developing software engineering curricula and enlarging existing institutions to feed their growing local industries.

Table 4. Software Workforce (Source. CSIA, p.12)

Year	Number of software professionals	Number of graduates in computers and software
1998	132,000	29,000
1999	150,000	33,000
2000	186,000	41,000

Despite the slow growth of software professionals, there did not appear to be major shortages of most types of personnel in the firms that we interviewed. A greater problem could be posed by the skills of the workforce. Only about 10% of the IT workforce has experience with complex programming tasks, and project management ability continues to lag India's.[10]

Because of the shortage of skills in China, the hourly wage rates for professionals (i.e., developers) with about 2 years experience are about US $12-25 in China, versus about $24 in India (Gartner, 2002). This reflects the uneven nature of the labor market.

Regional dispersion of industry

The regional picture is also enlightening. The table below shows key statistics for the top 7 regions (as measured by the number of companies, but many are also top in number of

[10] The Far Eastern Economic Review, July 11, 2002, p. 30

employees and other statistics), and the total for 25 regions (excluding Beijing, which has a very large number of firms).

Table 5. Key Characteristics of Major Software Producing Districts (source: CSIA, p.6-7)

Industrial District	No. Companies	No. people	Sales	Product Sales	Service Sales	Exports
Guangdong	1,500	40,000	135	47	78	122
Shanghai	600	12,637	48	11.97	11.6	7,276
Liaoning	600	15,000	40	25	12	-
Shaanxi	500	6,000	31.80	-	-	-
Jiangsu	2,000	12,900	25	15	10	-
Shenzhen	600	23,000	23.18	14.34	-	1,250
Shangdong	540	30,000	21.30	11.80	9.5	-
Total (25 districts)	8,682	184,622	473.72	155.41	130.60	17,009

Our sample includes firms from four districts that have major concentrations of activity: Beijing, Shanghai, Xian and Jinan (in Shandong province).

Beijing is by far the largest software producing district, with a balanced industry including packaged, industrial, and security software, as well as exports. Beijing's prominence is in part due to its being a center for government and leading educational and research institutions, as well as the base for a number of well-known computer firms. The software area in Beijing is located in the Zhongguancuan area of Haidian district, which has two of the leading universities in Beijing University and Tsinghua University, as well headquarters for and large facilities of a number of important early IT companies, like Founder.

Shanghai has fewer companies, but is a leading center for overseas investment, finance, and high-tech industries, including electronics and semiconductors. The infrastructure, universities and government support in Shanghai are also very strong. However, a well-known and puzzling fact is that despite these advantages, Shanghai is still not known for any sizeable software companies, other than systems integrators. Shangdong has been a center for heavy industry, and is developing a number of companies focused on industrial applications. Finally, Xian is the leading industrial center for the western part of China, and also has a strong software push. Some of Xian's policy is focused on the export market, but there are some domestic product companies as well.

Other regions with heavy concentrations of high tech also have heavy concentrations of software firms, e.g. Shenzhen near Hong Kong (where Huawei is headquartered) and Guangdong in the South coastal area. However, the software activity appears to be quite dispersed across the country, and some cities like Chengdu in Sichuan province or that do not even have large numbers of firms may have at least one large well-known software firm.

Structure of the Industry: Products vs. Services

By looking at individual firms, some not so obvious details emerge. Many of the largest firms are doing either systems integration, or a combination of products and systems integration. This translates to regional differences as well. According this classification, Shanghai has 9 out of 13 firms that only do systems integration (a lower value added kind of work), while

Beijing has only 5 out of its 17 firms in systems integration, the rest being either in products or some mixture of systems integration and products. This suggests a lower level of capability at least in these particular Shanghai firms.

Clearly, the differences between these two types of activities will have to be clearly defined before we can continue our analysis.

We define product work as the developing of software that is copied or duplicated for anywhere from a few copies to many copies. In some cases, each copy is changed or "customized" according to user needs, while in others, each copy is identical, and the product is known as a "packaged product". Some products like certain firms' enterprise resource planning software packages have to be 50% customized. In all cases, the maker of the product is compensated for the full value of each copy, i.e. the intellectual property is owned and sold for each copy.

Services on the other hand involves doing the work, which may be product development, as a contracted activity for which the firm is compensated for the task or the hours spent.

In China, a third form - what we call *project work* - may exist, and may be an intermediate form between product work and services. This type of work allows the developer to keep some or all of the intellectual property, and to make heavily customized copies for additional customers, i.e. additional semi-customized product.

It is quite likely that some of the "product" work that many firms claim to be doing is arguably more appropriately called "project work" or "services", since they are done on a custom basis and charged on a contract basis, and thus are not even close to "packaged products" with brand names. Since, at this early stage of the industry, branding may still be a problem for many firms, customized products may be the norm, and where the intellectual property rests may dictate the final definition of the "product".

3. Research Methodology and Selected Companies

Our research focuses on a selected sample of firms to substantiate the previous observations about China's software industry, as well as to uncover other previously unknown issues. All of the firms we have interviewed in our sample make some type of product. However, many also combine this work with systems integration and other forms of services, either for revenue generating or value adding ("total solution") purposes.

3.1. Description of Sample of Software Sectors and Firms

Because of the diverse number of types of products, we will group our sample into four major product or service categories:

- Applications software – including business applications, security, and specific consumer and other products (e.g. education, spatial applications)
- Systems and networking software – including operating systems, middleware.
- Infrastructure and industrial applications software – including construction, telecommunications and electric utilities, industrial applications like power management (some systems software can also be classified as such)
- Export services

We will use the evidence from our sample of 27 firms to corroborate or refute the conventional beliefs about the industry, namely, the beliefs that Chinese software firms are weak and small, that they may suffer from high employee turnover and weak processes, and piracy, and whether the firms exhibit the same origins as the IT hardware industry. We will also examine the other factors which may contribute to a firm's health and competitiveness.

We interviewed each company with a semi-structured interview. The questionnaire included questions on their work, the structure of the sector they are in, their origins, their capabilities, (including human resources, process and management issues), and other issues that cut across the sectors.

Characteristics of Study Sample

The table illustrates the companies listed by their product type. It can be seen that the firms sell to one of three types of markets: end-user consumers, end-user businesses, and other manufacturers which embed the software in their products, e.g. hardware makers. The level of competitiveness varies, depending on the level of technology needed, but for the most part, most sectors are competitive.

Table 6. Attributes of 28 Firms Interviewed (Categorized into Sectors)

Sector	*Subsector (Customer Type)*	*Firms interviewed*	*Market size, character*	*Technology*
Application Software	Consumer Products (end users)	Education:Human Technology Translation: Kingsoft*	Few to many strong firms competing	Low (education) to high (translation)
	Business (firms)	Finance: Kingstar*, Digital China**, CVIC*, GrapeCity	Many firms competing	Low to medium
		ERP: Calkai*, But One, Cheelosoft*, Sunny *	Many firms competing	
	Other Industrial/business Software (industries)	Security: Anyware, Tsinghua DASCOM, Shanghai Fudan Grand Horizon*	emerging, competitive at low end	Low (firewall) to high (network security)
		Spatial: Supermap, Beijing Listen	Moderate competition	Low (GIS) to high (GPS, integrated)
Systems and Networking	Middleware (firms)	Tongtech CVIC*	Competition from multinationals	
	Operating systems (industries supplying end users)	CASS* Hopen (product name), Red Flag Linux	Low competition (customers are manufacturers and consumers)	Medium to high
Infrastructure and Industrial Applications	Roads, construction (businesses, industries)	Netsky CVIC* (toll roads)	Moderate to competitive (local markets)	High (complexity of large teams)
	Power applications (businesses, industries)	Cheelosoft SEPCO		High R&D content
	Telecom (businesses, industries)	Shandong Luneng Jicheng (SLJ)*, Digital China** TongFang Huawei (internal software)	Scattered (moderate to high for power industry)	Low (MIS) to high (telecom)
Export, other Services	(businesses, industries)	Chongran** ASTI* Suntek (training) ICE (embedded software design house)	Emerging	Low (coding) to medium (systems)

* companies with up to five lines of business
** companies with more than five lines of business

(1) Application Software

End User Consumer Products: Translation and Educational Software
End-user software applications ranges from companies engaged in more technology-intensive software like translation software, to more domain knowledge-rich subsectors like educational software. Most are resident on the PC platform.

Business Applications (e.g. financial packages)
The packaged software market for business appears to be very competitive. In some areas, competition is fierce, because the technology is relatively low level and accessible to many new entrants.

We interviewed eight firms working in the area of ERP and financial software. In highly competitive sectors like financial software and ERPs, certain companies have emerged as market leaders with high growth rates. Examples are CVIC, Kingstar, and Digital China. CVIC's banking and accounting software is used in banks and other companies needing financial systems. They have a broad customer base, with over 60,000 locations using their products.

Some companies are quite specialized, like Shanghai's Kingstar, which only focuses on certain financial products. Other companies are diverse, e.g. CVIC and Digital China. Digital China covers not only financial (banking) but also government tax, telecom and ERP products. Digital China was originally a part of Legend computer, one of the largest and most famous of Chinese PC makers, but was separated recently as a purely software arm. Kingstar is a medium sized Shanghai company which specializes in software for large financial applications, e.g. stock exchanges, banks and exchange markets. They have now obtained a national market share of 70%. They have no competitors in exchange markets, only three that produce stock exchange software, and many competitors in banking software.

Other Application Software, e.g. Security Software, Spatial Applications (Geographic Information Systems or GIS)
There are numerous other niche type software areas. Security software is a major emerging sector in China, in part because of the Chinese government's concerns with protecting its systems and data. This has led a number of companies to emerge in this sector - reportedly about 230 (CSIA, p. 177), making it very competitive. However, the technology in this sector can range from the simple (e.g. desktop security like virus checkers) to the complex (e.g. network security based on university research). Thus, the degree of competitiveness depends on the quantity of R&D that can be embedded (with the more R&D, the more a firm has a competitive advantage).

We interviewed three companies doing security software: the medium-sized[11] Shanghai company called Fudan Grand Horizon Information Technology (Grand Horizon for short) focuses on network security (amongst other areas), including intrusion detection for networks. The Beijing-based Anyware works on desktop PC security as well as network

[11] Regarding revenues, [illegible]

security. Tsinghua DASCOM, an offshoot from another Tsinghua company, was formed to develop security products. They did so as it was difficult to work within the auspices of the university.

Another subsector is the spatial applications or GIS software that may be packaged and sold to either consumers or manufacturers. The Chinese market for GIS and other spatial applications software is quite strong, ranging from security systems for provincial police agencies and homes, to embedded software for electronic products manufactured by others. We interviewed two firms working in this area: Supermap and Beijing Listen. In each of these, the combination of geographic expertise (i.e. domain knowledge) with software has facilitated work in spatial dimensions, and increasingly, other technologies (e.g. distributed technologies like wireless) has helped the firms to enter markets. One of the main American software brands – ArcInfo – appears to provide costly "all or nothing" packages, which allows the Chinese firms to enter the market with lower cost, incrementally priced (according to the number of modules one selected) strategies.

(2) Infrastructure and Industrial Software

Infrastructure and other large projects (e.g. telecommunications) have become an important area in which Chinese software firms have been able to grow big relatively quickly. Our sample contains four firms in this sector. The three companies in our sample from Shandong all developed software for very different applications. Nevertheless, all three were connected to some local or provincial industry.

(3) Systems and Networking Software

Systems software like operating systems and middleware requires fairly advanced or new technology. China has had a few companies that were successful at developing their own operating systems, but this appeared to require a large internal market that could support their sale.[12] We interviewed two firms that were very strong in operating systems and two that were strong in middleware. Their strengths came about partly because these are areas with barriers to entry (i.e., ones where few domestic competitors can compete in due to a lack of capabilities), and partly because there are emerging market opportunities in China.

(4) Services

It is not possible to make sense of the Chinese software industry, particularly its path to products, without understanding the role of services in the picture. This will also help us differentiate the nature of Chinese software services from Indian software services.

Services in China can be divided into at least 4 categories:

1. Customer service, which is often provided free of charge, but which firms can use to gain a competitive advantage amongst technologically weaker customers.
2. Consulting services to help define the software to customers' situations, and even to improve customer business processes.

[12] While in some respects, operating systems - the basic software that under girds computer systems - are a fairly accessible technology that even undergraduate computer science students learn in class, in practice, to develop

3. Systems integration, which is one of the lowest level of services, and is at its simplest the connecting together of “off-the-shelf” (i.e., commercially available) hardware and software into information systems.
4. Outsourcing services, which are services provided to a customer to develop or service an application. A service is work which cannot be carried over to the next customer, since the first customer owns the intellectual property.

As noted earlier, the grey areas between services and products can complicate the process of classifying firms. Even more important, there are important relationships between services and products, so understanding services like customer, consulting and systems integration services can help us to understand the complexity in the Chinese products market. (These appear regularly enough in our interviews with product companies to warrant greater attention.)

One such “relationship” is that many firms combine or package their software product with customer service or a systems integration “solution” so as to help add value to somewhat less sophisticated customers. Customers in China do not have enough internal information systems expertise, so they rely on the software or systems integration vendors to help them. At the higher end, consulting can also help these less sophisticated customers to deal with systems implementation of services by integrating the software solutions with their business processes.

4. Analysis of the Conventional Beliefs

The analysis of the software industry yielded several insights into the conventional wisdom on the following:

(1) The origins of the software industry
(2) Small and weak firms
(3) Weak industry capabilities
(4) Other problems such as high human resource turnover and piracy.

We will examine each of these in turn.

4.1. Origins of the Chinese Software Industry

4.1.1. Origins of the General IT Industry

The origins of the Chinese software industry is intertwined with that of the broader IT industry, especially the PC industry. Thus, it is worthwhile to examine the models on the latter that other scholars have developed.

The earliest and most well-known IT companies have their origins in a variety of sources, with the more technology intensive ones coming from the various government research institutes, universities, and “greenfield” startups. Four important modes of IT industry firm formation have been identified earlier by Lu (2000), and form much of the basis of the brief analysis in this section:

1. The model of spinoffs from the government-funded research institutes in the Chinese Academy of Sciences – as represented by Legend, a PC language card maker that became a full-fledged PC manufacturer.

2. The model of university-researched technologies being commercialized by private enterprises which were funded partly the university and partly by other agents – as represented by Founder, which got its start developing electronic publishing systems, but is now also a major PC manufacturer
3. The model of spinoffs from a state run firm – represented by Great Wall, a PC manufacturer
4. The model of a greenfied startup – represented by Stone Group Corporation, a company that got started by university graduates, and whose first products were word processing products.

In these earlier success stories, the issue of software and hardware is intertwined, since many of them developed technologies that involved some amount of software, often embedded in hardware. In all of these, the government has had a profound influence in its provision of intellectual capital, training and incentives. Thus, a review of this setting provides a worthy starting point for understanding the Chinese software industry.

Influence of the Government

The Chinese government has assisted the hardware industry in more ways than one. Firstly, it helped in assisting the model represented by Great Wall to be realized: by allowing a state run computer company (one of many) to become privatized as a successful PC maker.

The Chinese government also had an early influence on the software and hardware industries by its sponsoring of national research efforts on "core technologies" deemed essential to the nation's computer industry. Some examples of the projects include various large scale government funded projects dedicated to developing Chinese competence in core computer technologies, such as the Ministry of Science and Technology's 863 research program, and other government research projects that became the basis for Founder, Legend and other companies. More recently, a series of government "Golden" projects were started to expand the country's e-commerce and infrastructure and the various sectoral applications, e.g. e-government (Lovelock et al, 1997).

Perhaps the government's most important role comes through its support of national research and development in the several dozen research institutes of the Chinese Academy of Sciences (CAS), a number of which also participated in the development of these core software and hardware technologies. The CAS institutes for computing, software, and natural resources were three that we interviewed which had spinoffs.

Finally, another phenomena commonly seen in China is the use of government procurement, especially at regional and municipal governments, to enable local firms to bid for and supply IT systems.

Origins in Universities and Scientific Research

Many of the more recent software arrivals have come straight out of universities. A few well-known Chinese hardware firms got an earlier start as spinoffs from universities, usually as a result of some combination of software and hardware technology. These in turn have given rise to software divisions, or even software spinoffs. A case in point is the well-known PC maker Founder, which had roots in Beijing University research on font processing and pictographic publishing systems. Founder illustrates how the combination of this government

supported research, coupled with private sector investment and entrepreneurism, succeeded in the creation of what became a leading PC maker (Lu, 2000).

The other model is that of Legend, which started with a number of professors leaving the CAS Institute of Computing Technology, eventually becoming another leading PC brand like Founder (Lu, 2000, p.63). Legend came about because the government investments in research on Chinese language gave the scientific team at the CAS Institute of Computing an important technological edge, which was translated in the spinoff to a specialized computer add-on card, and eventually into PC system manufacturing prowess.

Stone also got a start at the software-hardware nexus, but it did so by specifically designing Chinese character software to be combined with a Japanese printer. Coupled with lower cost advantages, they were able to gain strong market share. Although Stone was started as a Tsinghua University spinoff, it also took advantage of talent from the CAS, which was crucial to its products (Lu, 2000).

Thus, it is reasonable to say that the research institutes served not only as a nurturing ground for technology, but also as a holding area for scientific and engineering talent, keeping them engaged until the right time and private sector opportunity emerged. Otherwise much of the scientific talent would have gone to seed in other diversions. However, although this often originated in government research giving them a competitive edge, these companies were created and made successful by the combination of “private” efforts (e.g. university entrepreneurs and private investments) and public financing of research. It is worth reiterating that some of the earliest and most well-known PC makers were based on some kind of technology related to software.

4.1.2. Origins of the Software Industry

To verify the existence of these same “spinoff“ models in the software sector, we examined the origins of the firms in our interview sample. In addition to the university and CAS startups, there is the additional source (and complexity) in the software sector because of the ties between the already existing hardware sector and the newer software firms. The early hardware firms established themselves in the market for both personal computers and highly specific types of software technologies, such as character recognition. However, they did not have much capability in systems and application software. Over the years, many have established software arms, such as the Legend Group, which recently separated its software arm and renamed it as Digital China. Another special source of software firms is the systems integration business. The rise of the hardware (i.e., PC) sector accompanied the increasing use of computers in Chinese business and society. Along with this came a large number of firms dedicated to systems integration, or the configuration and installation of hardware and software in different custom arrangements for customers. This was in part due to the lack of sophistication of customers, and was not unlike the early stages of US software applications development, where firms had to build customized applications for small customers. Finally, we cannot ignore the new breed of software firm that, much like Stone in the area for hardware, comes about largely through the private actions of individuals. Our sample has more to say about that as well.

Our investigation is further complicated by two issues:

(1) Some firms like Legend have a hand in all three activities: hardware (originally), software development and systems integration. This is done partly because systems

integration gives the industry a chance to promote their software as well as to make profits off hardware sales.

(2) The issue of identifying a single key origin in “greenfield firms” (i.e. fresh startups) like Stone is complicated because, even though such firms drew their first key employees from universities, they may also have drawn their succeeding key technical employees from other public institutes like CAS. In similar fashion, it should be recognized that in our sample, while the initial partners may have either a technical or business background from one or another source, the subsequent partners may have an alternative background to the founders, and come from other sources.

University Off-shoots

In our sample of about 30 firms, at least 6 firms arose from universities, either from students (2) or faculty (4). The firms spunoff by universities were Grand Horizon, SLJ, ASTI, and Calkai, Kingstar and Human Technology. In addition, three more firms were further separated from other companies that were formerly university-affiliated, namely, Digital China (from Legend), But One, and Tsinghua DASCOM, and some firms were setuo by recent university Ph.D.s who decided to become entrepreneurs.

Grand Horizon was established in 1988 by a group of professors from Fudan university - one of the country’s leading universities, located in Shanghai. Like many companies its size, the company has also diversified into multiple product lines wherever it saw growth and opportunity: network security, education and distance learning, broadband and streaming media, and touch screen technology.

Similarly, Tsinghua DASCOM, an offshoot from another Tsinghua company, was formed to develop security products, partly because it was difficult to work within the auspices of the university.

Kingstar was initially started by a group of postgraduate students from Fudan university, who took their project ideas from the university into the business arena. When they initially entered the market for stock exchange software, they found many competitors at a low level of technology. They decided to do a system architecture plan for their product’s evolution. Their first customer was a local stock exchange, which offered to help them if they could successfully develop a system. This became the first basis for their company, and is now the sector they derive the most income from.

Likewise, Human Technology was started by a group of chemistry graduates from Tsinghua University, who endeavored with success to produce educational software. Their offices are a stone’s throw from Tsinghua, and over 60% of the firm’s employees are Tsinghua graduates.

Despite Beijing University’s and Tsinghua University’s fame for having becoming involved in large numbers of startup companies, the local universities in other cities also have had a strong hand in enterprise creation, albeit with lower numbers. Two examples that we interviewed in other cities were SLJ in Jinan and Calkai in Xian. SLJ was started by a team of professors from Shandong University, who started their research on electronics automation in 1984. One of their founders brought back some ideas from the US of using PCs to do automation. Like SEPCO in Shandong, one of their main investors was the Shandong Luneng Power company.

Calkai in Xian was started by a group of faculty and former graduate students from Xian Jiao Tong University. (The director of the Xian software park also came from this local university). The shareholders include local corporations and Xian Jiao Tong University (which also invested in But One, which had split off from another firm to focus on ERP work).

Interestingly, all of the companies were started from faculty and students from local universities in the cities of the respective firms' origin. The fact that many were not Beijing-based suggests a substantial depth of university talent in China, and the geographically dispersed nature of that talent.

Increasingly however, the more extreme model of involvement represented by Beijing University and Tsinghua University appears to some observers to be threatening the autonomy and main mission of the university. These universities have set up technology parks next to their campuses, and are directly involved in a great number of spinoffs, both technology and financial wise. However, it has been suggested that the pressures from heavy private investments and other involvements would eventually conflict with the institutions' educational aims (discussion with vice president, Hong Kong University of Science and Technology). Beijing University has supposedly spun off several dozen companies, but the vast majority are not growing as well (Lu, 2000).

CAS Spin-offs

The model of firms spun out of the CAS institutes (as represented by Legend) is also seen in our sample. Two firms were first gestated in then directly spun out of CAS institutes (Supermap and CASS), while at least three more – Anyware, Red Flag, and Beijing Listen – used CAS talent. All mainly relied on private capital to help them start up. The two companies that produce operation systems – CASS and Red Flag – also had CAS backgrounds. CASS was a spinoff from the Chinese Academy of Sciences. CASS developed the important Hopen OS which was based on their earlier work on operating systems going back to the 1990s.

Red Flag is another interesting company of about 100 people, and which also competes with Microsoft. Like the company that produced Hopen, they also started from the CAS software institute. Their experience with Unix (the foundation for Linux) went all the way back to 1979, when Professor Sun at CAS started his research on Unix. The group decided to leave CAS. They started with venture capital from Hong Kong and Chinese venture companies, and have used product positioning, business models, and upper management with multinational experience to help them. In 1999, Red Flag started to research on Linux, an open source software substitute for Windows and other proprietary operating systems, and in 2000, the company started.[13]

Linux is an unusual platform in that it provides the company with unparalleled access to resources, namely the worldwide Linux community, which is willing to help test and refine

[13] Open source software is a type of software that is independent of any individual maker, so anyone can make it, contribute to it, and use it for free. However, more specific implementations of the software that rest on top of the base software and add more functionality or usability may be made privately and priced on the market, as with Red Flag's product. These will still derive the benefits of the "open" (worldwide) developer community,

pieces of code for the generic Linux base, while the company can focus its efforts on an effective implementation of Linux.

At least two companies spun off from the CAS institutes studying natural resources. One company, Supermap, develops GIS software for a variety of purposes, ranging from educational to vehicular Global Positioning System (GPS) applications. Another called Beijing Listen Information Technology has taken the concept in a different direction, combining GPS, GIS and remote sensing (RS) technologies into integrated systems. These are developed for police rapid response networks, and other home- and city-level security needs. In both companies, the leaders were PhDs familiar with geography, who studied and worked under a well-known natural resources scientist with information technology expertise.

Roots in Systems Integrators

Although there are doubtless many systems integrators that climbed the value chain and moved into software development, many of the very largest are still stuck doing a mixture of custom project work and systems integration. We interviewed only one firm that appeared to have exclusive roots in systems integration – Tongtech – although others in our sample had done systems integration work either before or were still doing so. Tongtech's story is a bit surprising in that they were able to move into and compete in a fairly sophisticated and not well-understood area like middleware, from such "humble" roots. In fact, their systems integration roots served them well, as it provided an element of customer service that they could use to compete against competitors and even multinationals.

Government Firms

About 30% proportion of the software industry is government-owned and a further 10 percent have mixed private-public ownership. We have interviewed one such company: ChongRan (one of the largest). However, it appeared that the usual difficulties associated with government enterprises may be making it hard for them to manage growth well. Amongst other things, ChongRan was trying very hard to break into multiple lines of business, but this spread its resources out quite thinly.

Comparing the Chinese Industry's Origins with India

The aspects of linkages between the formation of the product companies and university and government sponsored research and research institutes illustrates a major difference between the Chinese software firms' beginnings and those of the Indian industry's. Although many Indian firms did arise out of its defense industry or personnel from that industry (e.g. HCL), and from the hardware industry (e.g. Wipro, which was originally in a different line of business), many more recent Indian companies started immediately as export service companies (e.g. Infosys) or through personnel leaving multinationals, or by those leaving the first generation of companies like Wipro and TCS. Furthermore, many Chinese firms continue their liason and relationships with the research institutes in a continual process of appropriating fundamental technology, perhaps more so than the Indian firms, which source the bulk of their technology and techniques from the US and other multinationals.

4.2. Firm Size and Growth

The Chinese software industry is perceived by many observers, including the national government, to consist of too many (undesirably) small companies (Interview with various

officials). The conventional belief also suggests that many smaller firms are not growing, i.e., are not making much money. In part, this small size may be due to the recentness of the industry's development.

According to the CSIA, there are about 5700 software producers in the country (out of the 10,000 over firms dealing with software), but of the 5700 firms, only about 50 have above 1000 employees, and 70% have less than 50 employees. Of this total, about 30 percent are government owned, and 60 percent are private, and the remaining 10 percent are of a mixed parentage.

Furthermore, there is a great degree of variance, e.g. the hardware producing districts like Guangdong and Shenzhen and heavy industrial region of Shangdong have much larger numbers of people, and larger numbers of employees per firm that the other districts. This suggests that some districts have differing technological capability and type of activity, e.g. districts like Guangdong may have firms dealing with systems integration and other services.

To demonstrate another perspective, the city of origin of the 69 largest domestic firms (representing firms above 100 million yuan in sales) are shown in the table below. Size can be a measure of a firm's deeper capabilities, as well as the ability to carry out bigger tasks and projects. In fact, six of the firms in our interview sample appeared on this list.

Table 7. Number of firms with sales above 100 million yuan by city) (source: CSIA)

City	Number of firms
Beijing	17
Shanghai	13
Shenzhen	6
Hangzhou	7
Jinan	3
Nanjing	3
Others	10 (Xian has 1)
Total	69

These top 69 firms comprise about 25,700 million yuan in sales, which is under half of the total output of the software industry.

The main conventional belief is that the Chinese software industry is small and weak, a fact that on the surface would appear to be confirmed by the average size of 21 employees (taken across the 8,682 firms in 25 districts). While it would take a fully representative sample of the population to confirm this, what our sample can confirm is that a portion of the industry, particularly those developing products, consists of not so small (i.e. medium-sized) firms, and a further portion consists of smaller firms that are not so weak (i.e., growing quite fast).

However, it is important to recapitulate our alternate hypothesis: that small firms are not weak, and may even be growing quite fast. Furthermore, there may be large firms that are "weak" on capability. Of the table on large firms, nearly half of Beijing and Shanghai's largest firms actually consists of a high proportion of systems integrators – firms at a lower level of capability.

A difficulty in contrasting India and China is posed by the fact that many of the Chinese firms we interviewed have only been around in the last few years, whereas in contrast, many

of the largest Indian companies have been around for two decades, and have only reached their currently large sizes through a period of steady growth followed by a growth spurt due to the US market in the middle to late 1990s.

Our sample had a number of fairly good sized or growing firms. Of 22 firms that reported their size, about 8 were small companies, i.e. those with less than 100 employees (of which 4 had below 50), while about 11 were medium sized (between 100 and 500 employees) and 3 were large (above 500 employees).

The fact that there were a fair number of medium-sized companies with strong capabilities in each segment or product category suggests that there may be less of a need to be concerned with the small size of companies than with their capabilities, broadly construed. The fact that a longer time is needed for growth also hides the fact that the small-size of companies at early stages of growth may not reflect their fast growth rates.

Problems of the Weak

There are a number of reasons why such firms don't take off or sustain themselves, including financial reasons, poor execution on a strategy or model, poor product positioning or timing (ASTI), or too broad a focus (Calkai). In the case of ERP software, a specific problem is the lack of consulting capability to address customers needs or to help change the customer's strategies (Calkai). These are all the flip side of the factors that enable the successful and faster growing firms. Financing problems seems also to affect some firms that otherwise have good technology - Anyware and Tongtech (middleware) - appear not to have enough financing to continue stronger marketing activities.

Some companies are remaining small, or are not growing by leaps and bounds, which is at least partly consistent to the conventional observation on the small size of Chinese firms. Many of these may simply be resource poor firms in the very competitive low end. However, even firms with sufficient intellectual or technology resources can be stagnant.

Another difficulty that afflicts smaller companies is that they are too small to get the larger contracts (ASTI, Tongtech). Some that got into the wrong product market, suffered eventual death from lack of demand, high piracy, or other factors (ASTI). Another possibility is the intense competition – good technology or other distinguishing characteristics, e.g. pedigree, management, process capabilities (for later stages of growth), getting a good market entry and building on that etc.) may be keeping the less capable firms small.

However, it is also important to note that some small firms like CASS and Red Flag are doing well, in part because of their technological advantages or barriers to entry over the rest of the market and the recognition that there is a lot of potential in their respective markets.

Two of the three largest companies we interviewed also appeared to have problems with rapid growth and organizational structure respectively. These and other firms also appeared to cover an overly wide range of sectors for their size, which could be explained as a lack of focus. Even Top - one of the largest software firms in China – has not been able to escape the question on whether they are growing at the expense of capability. Top has 2000 software

professionals and is currently hiring 5000 more, but much of its work still consists of government contracts and systems integration.[14]

Growing Successfully

The interesting corollary observation is that the medium sized companies and some of the smaller companies with better technology appeared to be doing quite well, both in growth terms, and in their ability to mature into organizations with strong management, process and products. They were securing succeeding stages of venture funding, and appeared to have healthy growth in their revenues and markets. For example, Grand Horizon, CVIC, But One, Tongtech and SLJ are all medium sized firms that are doing quite well in their respective markets. All are expanding or have expanded into markets all over China, and in the case of SLJ and Tongtech, are managing to compete with multinationals as well. Tongtech has 30% of China's middleware market.

Grand Horizon now has over 300 employees. While it originally focused on network backbone security, it has diversified into multiple product lines wherever it saw growth and opportunity; namely, education and distance learning, broadband and streaming media, and touch screen technology. To improve the uptake of their products and market penetration, they have resorted to systems integration that combines their products with other companies' products.

Like Grand Horizon, the 500-strong Shandong company CVIC appears to have grown new lines of business without too much effort, having gone from accounting and banking software to large projects in the media and highway control. Initially, they could only manage small projects, but now, they have been engaging in a highway control system that involves about 100 people. In many of their products, high technology is important, e.g. a technology for character recognition used for bill scanning in their banking software product, and digital image processing used in their media product for the China Central TV (CCTV) station. They also focus on strong project management, and bring in many consultants to help advise them on their processes.

Similarly, Tongtech in middleware, But One in ERP software, and SLJ in power management software, are expanding in size into different regions. To be competitive at a medium scale, they have had to focus on a single product.

But One, an ERP company based in Xian, has around 360 employees and is growing fast by honing their ERP products for specific sectors. It spun off from another local company, which ironically has been finding it harder to grow. Its connections with IBM appear to have helped it, but more important perhaps is the level of investment, and mature management which has focused on process improvements and marketing strategies across China to help sustain the growth.

Size is becoming a critical differentiator between firms. Cheelosoft, with about 1300 employees in total (800 in telecoms), has been growing very fast over the last two years, in part due to the need to service large telecom customers. However, companies like ASTI recognize that they are too small to obtain larger jobs and need to grow larger. Companies

[14] [illegible]

like CVIC have already recognized this and managed to attain the necessary size to compete for larger infrastructure sector projects.

Thus, a firm's size can be a misleading indicator of its capability, since large firms that were spread over a large number of product lines or industry domains had lower effective efforts in each area. Even many medium sized firms (e.g. Grand Horizon and CVIC) were spread over multiple lines of business. What this does for their ability as they grow is still unclear. In addition, some companies (for instance, this may have been the case in Shanghai) have relied too much on large government contracts, and have not been able to develop their own innate technological capabilities.

In addition to other factors, one important factor helping firms to get started and to continue growing is the reasonably easy access to venture capital. However, except for firms in Beijing and Shanghai which sometimes get overseas venture capital, it appears the first investors in many of the firms we interviewed in the other cities, such as SLJ, SEPCO, Calkai, and But One, are largely local companies and institutions.

In summary, firm size is not an issue if: (a) we consider that some of the better small firms are actually growing, (b) that some firms that are not growing as fast are still quite influential in their markets, and have growth in technological and other capabilities, and (c) that growth in firm size is not as important as quality and may even weaken the industry if quality is ignored at the expense of the firms' growth (e.g. counterexamples of state owned firms). Firm size IS an issue when small firms wish to take on larger contracts, but cannot show the capability to do so.

4.3. Capability: An Explanation for Strength and "Weakness"

China's weakness in capability has been measured by the lack of software process capability. For instance, a recent report noted that India has 32 companies at level 5 - the highest level - of the capability maturity model, whereas China has just one. However, as we pointed out elsewhere, this measure alone is an insufficient measure of other forms of capability, such as the level of research and development (Tschang, Amsden and Sadagopan, 2003).

Further exploring the notion of capability is important to determining the strength of the Chinese software industry and its firms, and can help us to determine whether Chinese firms really are "weak" as has been observed.

In addition to process maturity, we briefly examine other dimensions of capability:

- Process maturity.
- Management capability.
- Technology.

We stress that in order to properly characterize the ability of firms to grow and succeed, a description of capability would have to address all of these, and possibly other dimensions such as the ones discussed earlier in the section on firm size and growth.

Process Maturity

On the whole, most Chinese firms are not at a high enough level of process maturity to compete with Indian firms. Using one of the main benchmarks for measuring software

process maturity - the Software Engineering Institute's Capability Maturity Model (CMM) - whereas at the high end, India has about 32 firms that have reached the highest level – level 5 – China only has one thus far (Gartner, 2002). Of the firms we interviewed, three had just started dealing with the CMM accreditation process, and six had reached CMM level 2 (of which three were now aiming for level 3). However, not being in the export service business, firms apparently need less process maturity than equivalent export-focused firms. Several product-focused firms noted that they only needed as much process maturity as would help them to improve their products.

A much longer road lies ahead for firms planning to upgrade their process maturity, especially since the highest CMM level (i.e. level 5) is the hardest to attain, although it requires demonstration of substantial organizational capability.

Companies that were growing strongly, such as But One, were focused very much on management and process improvements. But One noted that their biggest ongoing transition was to become a more process-oriented firm. As was noted earlier, as the firm grows, the ability to manage and control large projects becomes important. In this, firms have to manage for cost, time and technology development (CVIC).

While many Chinese firms we interviewed placed some importance on process improvements like CMM qualification, they recognized that this was a slow process that they could only do not so much to catch up but to improve their internal processes. This practical realization could in part be due to the product orientation of most companies. Companies focusing on software services were still rare.

Management Capability

In a related vein, management process also appears to be increasingly viewed as important to the development of broader and stronger organizational capability. Although we have not discussed this in much detail, medium sized companies like But One, CVIC and Grand Horizon were very conscious of the need to gain management and development process maturity.

Some of the companies we interviewed reported that they were building CMM capability into their organizations as part of a desire to develop good management processes for their development. In this respect, it is a highly rational approach to dealing with other pressing objectives and limited financial resources. But One noted that their biggest ongoing transition was to become a more process-oriented firm. As was noted earlier, as the firm grows, the ability to manage and control large projects becomes important. In this, firms have to manage for cost, time and technology development (CVIC).

Technology

Technology appears to be one of the most important competitive advantages that distinguishes the good firms from the weak. For now, we define technology in our case to be technology applied from strong research results (this will be discussed more in the next section).

The origins of these product-focused Chinese companies and their technology basis clearly contrasts with that of India, where technology often came through technology transfer from multinationals or learnt from the open market (e.g. programming languages).

Capability as a Differentiator in the Marketplace

The deepening of technological or other forms of capability can be one way to differentiate the better companies from the weak. There are many smaller, weaker companies who compete on cost alone, and in a competitive market, may make it difficult for the better companies to climb out of the stack. SEPCO tried to move to more technologically-sophisticated products at the higher end, so as not to compete with the many smaller companies who could not compete at that level, but this was difficult without the right skilled manpower (e.g. properly trained software engineers).

4.4. Other Conventional Beliefs

Other factors not unrelated to capability may also contribute to the "small and weak" perception of the industry. Since "weak" may be characterized in different ways, e.g. poor financing or capabilities, a necessary investigation must look into varying notions of capabilities. For instance, firms that are too small cannot bid for the large, complex jobs that would deepen their abilities. This perspective was reinforced to some degree by our interviews of firms. At the same time, many more small firms also compete at the low end of the market, resulting in even greater competition amongst firms. Recent developments also suggest that it is only a matter of time and desirability before these capabilities are improved. Educational systems are trying to catch up with the needs of the software industry, in both quantity and in specialized types of education, e.g. software engineering.

Human Resources

There is a perception that there are some problems with labor turnover and that this could contribute to the perceived problems of "weakness" in the industry. We set out to "test" this in our interviews with firms. None of the 30 odd firms reported a shortage of the main personnel, but several noted difficulties with getting high level business analysts and product managers, as well as other specialized people. It may be that product firms do not grow as fast, and that these being the "cream of the crop", may be keeping their turnover of key people low.

The wages in Beijing and Shanghai are the highest in the country, although average programmer wages in those places appear to be at or below Indian wages (averaging about US $1000 per month for experienced programmers or analysis in these higher paid markets). Although some estimates suggest that the IT market in China will see a greater disparity in demand and supply for professionals in China as it is in India, anecdotal evidence from our sample suggests that there is less of an upward pressure on wages that had been seen in India's recent past.

Piracy

Most of the firms that we interviewed did not consider piracy to be one of the most major issues confronting them, although it does exist on a large scale. One smaller firm ASTI did note that piracy adversely affected sales from one of their earlier products. The larger firms doing consumer applications and medium sized firms working with businesses had managed

to live with the fairly high piracy rates, so it appears that they are able to develop a revenue model that works at least for enough of the market to make them satisfied. In fact, some firms have noted that the ones pirating are probably ones who could not afford the software. Some also noted that one reason customers decided not to pirate was because of the (often free) customer service the firms would give (again, an artifact of the less sophisticated nature of many customers).

This perspective was reinforced to some degree by our interviews of firms, but there the recent developments suggest that it is only a matter of time and desirability before these capabilities are improved. Educational systems are trying to catch up with the needs of the software industry, in both quantity and in specialized types of education, e.g. software engineering.

5. Analysis of Competitive Advantages of Firms in the Domestic Market

One important discovery from our sample of firms is that China's domestic market advantage is actually due to a complex set of factors and relationships. The current state of academic analysis on the domestic market leaves important issues unsolved, such as the role of keen competition both domestically and from multinationals, and the competitive advantages that firms are developing, aside from the usual "sufficient quality of human resources, management skill, investments and first customers" that many claim.

In the sum of our observations, we believe that the key to answering the above lies in a combination of the following local abilities and assets:

(1) technological advancement of the firms (based on their origins in state-sponsored R&D). This is a form of "know why".
(2) product knowledge, which is the knowledge needed to develop marketable products. This includes knowledge of consumer preferences, and domestic business needs. This is a form of "know how".
(3) local domain knowledge, which is the knowledge needed to work with local business practices and technological and other conditions. This is a form of "know who".
(4) The knowledge of domestic firms' business process needs, e.g. consulting knowledge. This is a form of "know what others do".

We will examine the confluence of these factors in the following areas:

(1) The ability of local firms to work with domestic product manufacturers (usually consumer products) and to design products for consumer end users.
(2) The ability of local firms to work with local industries. At the beginning, firms may work with clients in the same city or province, but as they extend to different cities and nationwide as a whole, other capabilities and kinds of knowledge are required to be able to service the larger market.
(3) The ability of local firms to work with domestic businesses (i.e., businesses as end users), including the ability of local firms to compete with multinationals.

Table 8. Forms of Knowledge Used as Competitive Advantages in China's Domestic Software Industry

Type of industry\Competitive advantage	**Domestic product manufacturers, e.g. operating systems, PC desktop software**	**Local industries, e.g. power industry software, construction (one-time projects)**	**Domestic businesses, e.g. ERP**
R&D	R&D (where needed)	Development only	Development only
Product knowledge	Knowledge of manufacturer needs, customer tastes	Knowledge of customer business ???	Some product knowledge
Linkage with (highly) local businesses (same city or province)	-	links with local lead customers and their needs	links with local lead customers and their needs
Local business process knowledge, service	-	Systems integration	Customer service, consulting

In each of these four areas of activity, we will show how domestic firms have combined the different types of these local abilities and assets in order to create local or national competitive advantage.

5.1. Working with Domestic Product Manufacturers and End Users

It is in working with domestic manufacturers and end users that Chinese software firms are perhaps the most successful. It is also the one in which they are most known for their success. This is because of the clearer path to making packaged products, and the branding that is associated with it. The main kinds of knowledge include knowledge of consumer preferences and manufacturers' needs, and the ability to translate them into products, and where necessary, R&D. The first type of knowledge is something that only being "on the ground" in China can provide, and even then, is more useful in certain sectors like education and computer game software.

End User and Industrial Product Knowledge

The area of consumer packaged product software is one area where the numbers of consumers in China are most advantageous to the fortunes of software firms. Areas like language translation are ones where China has traditionally had some comparative advantage, and the local firms have dominated the language translation market. Kingsoft, a diversified company started by a successful businessman who had money to invest, has a leading translation product.[15] It also makes office productivity software and computer game software.

Education is another area where local products can be more suited to the local population's preferences than foreign imports. However, in educational software, technology is less important than the ability to appropriately combine different media with educational content. There are different areas of software even within this one sector. Companies like Human Technology (or Hong En) specialize in educational content, while others do specialized educational technologies as part of a broader portfolio, such as Fudan Grand Horizon, which develops videoconferencing based systems. Human focuses on children's education,

[15] To some extent, their strategy of moving from market to market as their last market gets occupied appears to

computer tutorials and language training. They only have about 2 or 3 serious contenders in their market, and hold a lions share – about 30% of the market (CSIA, 2000). The technology is not sophisticated in this sector, and most of their product development people are specialists in the fields of education and other non-computer areas.

Influence of R&D

In select areas like operating systems and security software, government sponsored R&D has also helped local firms create capabilities for superior products (discussed later). The PC manufacturers are ready clients for both packaged desktop software (e.g. office applications, translation software and operating systems). Operating systems like Linux have appeal in price-sensitive China market due to their lower cost than established products like Microsoft Windows.

Government R&D was also important in other sectors like security software (e.g. Anyware, Tsinghua DASCOM), and operating systems (e.g. Red Flag). In these firms, human capital also appears to be important, and the ability to form strong internal R&D teams, and linkages with external institutes doing research. Some companies have mastered technologies that China has a more natural advantage in, e.g. Chinese character recognition technology (CVIC).

Operating systems were viewed as an important area for national investments, and the central government funded early work in the Chinese Academy of Sciences' software institute, focusing on Unix type systems. This funding has paid off in recent years, especially when it became clear that Unix has certain advantages over the overly monopolistic Microsoft products. The two companies we interviewed are major players in the Chinese market: Red Flag, which produces a Linux variant that competes directly with Microsoft's Windows for PC operating systems, and The Chinese Academy of Sciences' Software Institute's (CASS) Hopen, which produces small operating systems that also compete with Microsoft's Windows CE for use in handheld electronic products.

The Hopen OS provided a clear example of linkages forming between software firms and domestic hardware manufacturers. Their product competes with Microsoft's smaller operating systems for running consumer electronic devices (e.g. palmtop computers), but because the Hopen OS is much smaller in size (requiring less memory) than Microsoft's equivalent (Windows CE) and can be flexibly tailored to a variety of products, they have had a fair bit of success. They have managed to secure contracts with large Chinese companies, e.g Legend's lower level products, and a TV maker. Their disadvantage is that they have lower amounts of capital and do not have the reputation of Microsoft.

Another example of R&D comes from the security sector, where companies have benefited by getting their technology from close association with universities and the CAS institutes. Anyware does this with staff from the Chinese Academy of Sciences, as well as the assistance of scientists and Ph.Ds from the CAS itself. They reported that it would have been very hard to create their company without the research institutes. Grand Horizon's network security products requires very strong technological capabilities based on long-term research obtained from the local university - Fudan. Less than a year ago, there were less than five companies across all three types of security software, but of the hundreds and possibly even more other companies that claim to be in security software, most are just doing systems integration work or doing rudimentary types of software, and what appears to differentiate

these firms is their ability to incorporate research from their past and present collaborations with these public institutions (interview with Anyware; Fudan).

However, one problem encountered by firms still loosely part of a research institute structure is the less business-like mentality of the staff and organization. According to one firm, it was not able to change its researcher's mentality overnight, although their younger employees could more easily change their mindsets. Some firms often got funding from the private sector venture capital, e.g. Red Flag Linux getting venture capital from CAS and CCID, an industry consulting organization. This plus their private sector management mentality helped them overcome the public sector mindset.

In other sectors, even though the state did not directly fund R&D, R&D seems to be an important factor in the beginning of firms, and an effective entry barrier to other domestic competitors. e.g. telecoms (e.g. Cheelosoft), Fudan Grand Horizon and Kingstar in Shanghai, Tsinghua DongRan in Beijing, SLJ in Jinan and Calkai in Xian are companies that originated from local universities, Kingstar in Shanghai. Many of the companies brought their technologies out from university projects.

5.2. Local Industry: Industrial Linkages Beyond Application Districts

Industrial software represents another area of customers. In this case, industrial customers manufacture and sell products which embed third party software, which is supplied by the software companies. This is an appropriate aspect of China's software industry to examine, in part because some firms in our sample (and many in the industry) get their start this way. The advantages conveyed to firms that work with customers located in the same province or city is based in part on the web of connections, as well as who they know and can help to improve their information systems. It also requires some product knowledge, which may be rudimentary if the firm is at an early stage. As opposed to starting with more advanced R&D, which is a "leapfrogging" approach, many of these local firms engage in a slower technological learning process, and many do not graduate to more nationally established levels. Firms that can breakout to sell to the whole country or other provinces have to develop yet another level of "local knowledge", that is, the knowledge of working with local firms. This requires more robust business and marketing models that can "scale up".

Some examples include the firms working on software for large customers in the transportation infrastructure sector (e.g. CVIC), construction sector (e.g. Netsky), the telecommunications sector (e.g. Jinan's Cheelosoft), and the power sector and power equipment (SEPCO and SLJ in Jinan). From the companies we interviewed, in some sectors such as the software sector in Jinan, there does appear to be a cluster of software firms in certain cities that cater to local industries as customers. As a consequence, they tend to have a base of strong local customers within their own provinces – a form of "application district" as observed in Saxenian's study of US software clusters. Companies like SLJ and Tongtech are managing to compete with multinationals as well.

Again, because these one time projects are effectively services for specialized software, the Chinese firms have an advantage, since multinationals are not in the game of providing such services. It is simply too labor intensive and the lack of increasing returns makes it only worthwhile to specialized service firms.

One-Time Only Software Projects

Some of the software created – such as CVIC's system software for toll roads - is of the large, complex, one-time only project variety, so they resemble the contract export services in the Indian software industry, with the possible caveat that because Chinese clients lack IT knowledge, the software firms may have to carry more of the requirements analysis and top level design, albeit for simpler technologies, than the Indian service companies.

Power Software

The Jinan company SEPCO develops software for both the back end (office automation) as well as the front end (running power plants). However, it faces a market with a large number of competitors.

The Shandong Luneng Jicheng Company (SLJ) is not related to SEPCO (which also has the name Luneng in its Chinese name), nor is it in the same field, though they did have one of the same investors – the Luneng power company. They develop products containing software for electric network automation, e.g. automation of electric power dispatching. While their products currently support only the electric power industry, they will be branching into other industries. They only have two or three competitors in China at the moment, and they also compete with foreign companies like Siemens and ABB.

Telecom Software

Shandong Langchao Cheelosoft (or Cheelosoft) is a large company that is growing quite fast. They have just been listed on the stock market, which has helped them to attain a very large size quickly. They work in the areas of ERPs, finance, telecoms and exports. In their telecoms work, they do both software development and systems integration for telecoms companies. Their telecoms product helps manage telecom networks, with multiple protocols, media etc. In China, there are many telecom operators, many with different protocols, which causes a complex problem for software makers. This is unlike the situation in the US, where telecom operators tend to own their own software arms, e.g. MCI and AT&T's network divisions. Domain knowledge is also very important to this industry, since they have to know how to develop for the specific technical requirements of the client.

Telecom equipment makers like Huawei in Shenzhen have different needs, and they often have larger internal software divisions, and so the competition is not really amongst independent software makers. The construction software sector has less competition, but the fragmentation of markets and standards makes it difficult for companies like Netsky to grow. This sector also requires people with strong domain knowledge of the construction industry.

Marketing and the Nature of Chinese Markets

Our examination of "local" software firms and their "local" advantages suggests a generic path by which firms form their first competitive advantages. This however is superseded by a broader or nationwide strategy, which then distinguishes the stronger firms from the ones that have not been able to "break out". This depends a lot on marketing, and the special nature of the local markets in China.

Marketing is one thing that almost all the firms we interviewed professed to be very weak on. Even rapidly growing companies like But One noted that much work needed to be done. Sometimes, marketing problems could be due to location, e.g. But One being located in the western city of Xian. However, larger firms could locate branch offices all over the country, including key cities like Beijing (e.g. Digital China).

The markets in China have some unique characteristics. Relationships are very important in Chinese markets, and many times, the best technology does not win the bid, but rather, the best relationships or a local company (Xian software park, SEPCO in Jinan). Thus, while the bidding process appears fair, in reality, it is not (SEPCO).

On top of this, market fragmentation and intense competition within local markets from local software firms coupled with protectionist procurement policies, as well as foreign multinationals at the top end, are all important factors that hurts many companies.

Many software markets (i.e. industry sectors) are quite crowded (i.e. competitive) and fragmented, e.g. Netsky in construction management software, and SEPCO in the power industry software market, sometimes by design and sometimes by nature, e.g. differing standards (e.g. SEPCO).

Some software companies have a high level of integration with domestic high tech manufacturers, in part because of the competitive nature of hardware manufacturing, where having the best technology really matters. Companies like Hopen and Red Flag have been very successful at selling and packaging their products with such manufacturers, in part because of superior technology.

To deal with this problem of fragmented markets, many software companies which do not have the sales or marketing teams do away with the need to have large sales teams because they work with other local systems integrators to sell their products as part of a system solution.

5.3. Working with Domestic Businesses

ERP and Financial Software

There may be hundreds of companies developing ERPs for very local markets, but many may only be doing it for one client at a time, i.e., it’s more like a contracted service for a client than a packaged product that can be resold to other clients. Its quite likely that many of these firms that claim to be developing ERPs may in fact be developing MIS systems (or precursors to the ERPs of today), rather than the full fledged ERP systems that corporations use to tie together their enterprise functions. The other type of business applications software that appears important in China is financial software, which many small and medium sized firms use. It is easier to build up a portfolio of thousands of clients for software like this.

One of the keys to working with domestic businesses, especially the small and medium sized firms observed in our sample, is the ability to service their customized business needs while providing competitively priced and adequately featured software. Thus, while these business systems are not state of the art, and some smaller customers do not require much, more expertise and experience is needed to service more mature and complex customers. Enterprise resource planning (ERP) software is one such application. In the ERP area, many

small and medium sized Chinese customers' tend to lack sophistication in information technology or business processes, so the success of the ERP implementation depends strongly on strong consultancies that can work with their customers to implement their systems. Unfortunately, the external or foreign consultants are too highly priced, and the smaller clients will not be able to pay much for this type of knowledge. At the same time, this lack of client purchasing power means that multinationals like IBM and SAP will not be willing to work in this market. Companies like But One which have a good internal consulting operation may be more successful.

The challenge in working with ERP systems is that in order to expand, a larger client base must be serviced. But this comes at an expense – the high variance in client needs and types of business processes requires some ability to manage the diversity of services-related needs that clients require. One strategy adopted by But One was to focus on clients in a single segment – the telecommunications sector. They also have consultants who know their clients' business processes. This contrasts with two other companies we interviewed (not named) which failed to provide sufficient consulting or to change the client's mentality enough to be able to help effect true business transformations with their systems – a common cause of ERP failure.

Other companies in our sample working in the ERP or financial software business were CVIC, Kingstar and Digital China. All three do what is called a "half-finished" product, which then needs to be customized for individual customers. This could in part be due to the lack of standards amongst their customers, especially those in different sectors. Digital China's ERP systems contain a high level of customization. Their information systems for telecom companies fair even worse due to changes in government policies. Similar standardization problems pervade other user industries, e.g. power and telecommunications (discussed later).

Thus, in general, this mix of capabilities between service and technology development can be important to firms wanting to create a competitive advantage, but the difficulty is in how to develop a business model (and the requisite mix of products and services) to allow expansion.

Product Knowledge: Competing with Multinationals

In the absence of formally funded government R&D, the domestic firms also developed products based on their own "R&D", i.e., the learning of new technologies, and their application to (or product development for) the Chinese space. Middleware[16] is an area increasing in importance since, as the Chinese domestic market matures, they will need to purchase new software that either work as integrated and modularizable business applications, or to hook up their existing systems with more sophisticated products and in more sophisticated ways. There are only three or four companies that can do good middleware products and solutions in China, of which we interviewed two: Tongtech and CVIC. The small number of firms may be because it is difficult for companies to get into the middleware business, needing a combination of familiarity with the technology and ways to package and sell it that are quite different from PC applications. In fact, until about 2001, it was difficult for companies like TongTech to get customers to understand and use it, and they had to devote much effort to the education of customers, sector by sector.

[16] Middleware is essentially the software that acts as an interface between applications and the network

Tongtech is one of the more successful specialized middleware companies in China. It started life as a systems integrator, initially decided to become a combined products and systems integration company, but in the face of other systems integrators' distrust of Tongtech's linking of products and systems integration services, Tongtech decided to focus on middleware products exclusively. They are quite successful, having sold about 100,000 licences for their product and controlled about 30% of the market (IBM and BEA systems holding the other two leading market shares). However, they now face increasing competition from established foreign firms like IBM and BEA, which are trying to undercut them, or which bundle their middleware with their solution services.

Another company that diversified into middleware was CVIC in Shangdong, which also developed transportation infrastructure and finance software. CVIC's approach was more mainstream, in which they tried to integrate middleware into their solutions, so in this respect, they are partly like Tongtech, integrating middleware products with SI activities. With their systems integration capability, they can do an entire solution with middleware, and they want to develop applications for multiple platforms.

The Overall Impact of Multinationals

In general, multinationals offer very strong competition in the packaged software sectors, especially in middleware and certain consumer software like operating systems and office productivity products (e.g. Microsoft) and software for business (e.g. Oracle). These can be priced low because earlier development costs can be leveraged over many copies in domestic market, but the more customization is needed, the more domestic companies have a "service" advantage, albeit one with lower profit margins. However, while some multinationals are still somewhat tentative in opening larger China offices or engaging in large sales, perhaps because of the difficult to penetrate markets, others like Microsoft and IBM are there in a big way. Both have large research laboratories that contribute to their worldwide R&D operations and products.

5.4. Export Services

The overall sales in software contract services (done for other clients especially in the export market) is still small. The limited experiences of many companies, like Luneng's work for Japanese power companies, Chongran's MIS work for a Japanese electronics client, and the experiences of Xian's software companies, are still too limited to paint a general picture of their export work. But it appears that it will be difficult for them to grow quickly in the same way that Indian companies have grown. The Japanese market takes much time and effort to cultivate, client by client, and whether the same experience from one client can be transferred to another client remains to be seen. Thus, it is possible that if China depends on the Japanese market, the kinds of growth rates based on multiple clients that Indian companies had seen will probably not be seen for a long time in China.

To this end, some regions of China that have a number of companies have started to develop networks or associations to help companies with exporting or other local industry initiatives. For example, an export league in Beijing was started.

7. Conclusions

From our research, it is quite clear that the Chinese industry's orientation clearly substantially different from India's in that it had a large number of companies focused on making products for the domestic market. Its basic structure has been identified as a mixture of product firms (who also do some mixture of low and high end services), and low end service firms. It is clear that the Chinese domestic market (and therefore the industry) has some advantages, such as the large and growing manufacturing, business and consumer markets. However, the competition from multinationals is especially strong in the packaged software and high end markets.

We illustrated the importance of addressing the strengths of the firms and industry via multiple dimensions, including the factors affecting firm size and ability to grow, the firms' capability, and the types of knowledge that can form domestic competitive advantage.

Small and Weak No Longer?

We also attempted to test the conventional wisdom about the Chinese software industry. The first and most important was the perception that it was small and weak. We found that the industry, while consisting of smaller firms for the most part, was not as weak as first thought. If weak was defined to be firms that were straggling along without much growth, that was certain to be true of most of the firms – as befits a newly formed industry with a large shakout to be endured. However, we also found some strong firms – defined as growing reasonably well within their niches, and making an impact on national markets. There were better companies with the capital to grow, and revenue to chase. In many sectors however, market size and structure (i.e., too many small firms and lack of markets) were the main problems affecting firms.

The conventional wisdom about problems with piracy and the lack of process capabilities was to some extent true, but not to the extent that they were believed to inhibit the industry. The piracy issue exists, but appeared manageable according to most of the firms we interviewed. The process issue was being addressed internally in many firms, but was less critical to product firms. A host of other issues appear to affect firm size, and should be looked at more systemically in future work.

Origins

In the process of analyzing the data, we also substantiated that at least part of the software industry shared the more distinctive aspects of the Chinese hardware industry in common, which is that many product firms had government research institute or university origins. About one third of the product firms in our sample originated in the local universities and public research institutes, and about half of the product firms had key personnel from those institutions. There was at least one firm (and perhaps many more) that managed to move from systems integration - a different, lower-end activity - into products.

These circumstances also represent a "different path" from India's, whose first generation of software firms essentially originated from different kinds of places, including the government, family-run firms, the hardware industry, and other non-software related industries. Many of India's second generation of firms (e.g. Infosys and Mindtree) were

started by people who had experience in the first generation, and founders of some of the recent startups also had multinational experience.

Linkages with Domestic Sectors

In a clear support of the breadth of the domestic sector, it appeared that the software firms in our sample developed applications software or serviced a range of domestic needs, including product manufacturers, local industry, businesses, and consumers. For instance, linkages between the Chinese software firms and manufacturing firms were directly shown in a few cases, for instance, CASS' production of the Hopen operating system (OS), Red Flag's development of a Linux variant that was supplied to PC manufacturers, Supermap's development of embedded GIS software for electronic communication devices, and SLJ's development of software for power management products.

What was also important in this were the various forms of technological and local knowledge needed, such as knowledge of both national and (highly) local customers' needs and processes (collectively called local domain knowledge), product knowledge, and R&D on both leading technologies like Linux as well as China-specific technologies like language translation. These forms of knowledge were key to many good firms' ability to compete effectively against other firms and multinationals, and in some cases, to become leaders in their respective sectors.

Competition with India on Export Services?

Our sample clearly indicates that most of China's product-focused firms were geared towards the domestic market, and in fact, had too much on their hands just trying to survive there, let alone think about exporting products or getting into export services. Furthermore, the firms in our sample had lower process capabilities than Indian firms, as well as more of a products focus. The firms that were planning to get into the export market were still at an early stage, and their capabilities were far from being equivalent to Indian firms'. Even the Chinese firms that were good at products did not necessarily have the capability equivalent to service, namely, ability to produce at high and productivity and efficiency. As such, the few firms that were geared towards exports were mainly in lower level export services, such as doing onsite programming work in Japan or localization of content and software for multinationals for the China market.

A Double-Edged Sword

In summary, the Chinese model is quite different from India's in its pursuit of a domestic-led growth strategy. The linkages with China's domestic market and industry were clearly an advantage, although competition was extremely keen, to the point where, as standards, technologies and markets mature, there is likely to be a large shakeout of firms in the coming years, given the general nature of industrial evolution. In the more technologically advanced sectors, there was also keen competition from multinationals, at least in the highest revenue areas.

The Effects of Policy

As noted before in the section on firm origins, the national government has promoted some parts of the software industry indirectly. In areas like research and regulatory formation, the government has been at its most effective.

For instance, almost all of the security software firms were based on university or government research. Anyware is one of only three or so in the world developing a certain type of security software for public key infrastructure. They do this with the assistance of scientists and Ph.Ds from the Chinese Academy of Science. While many of the security firms were responding to the needs of the private sector for security software, and the Chinese government's needs for security, the information security laws that have been passed have created a mini-boom within even this dynamic industry.

Another effect of policy that is more uncertain is the effect of current promotional efforts by the national government to increase the size of firms. While some firms use their listing in government "product excellence lists" as marketing tools, which is fine, it is circumspect whether other government policies, such as purchasing policies, designed to promote the large firms, actually help. Some of the larger firms are state owned, and may have weak capabilities. Simple policies that promote them without structural change may actually continue the "dominance of the weak".

Similarly, there appear to be huge amounts of investment in infrastructure, and specifically, software technology parks, a lot of it with explicit national government support, in a number of cities in China. Whether all this is more a real estate and "branding" phenomenon or something important is yet to be determined.

References

Arora, A., V. S. Arunachalam, J. Asundi and R. Fernandes (2002). The Indian Software Services Industry, *Research Policy*, 30(2001): 1267-1287.

CSIA (2000). Report on the Chinese Software Industry 2000, China Software Industry Association.

Gartner (2002). Comparison: Indian and Chinese Software Services Markets. Gartner Research M-16-1762, May 2002.

Gartner (2001). Financial Software Selection for the Chinese Market, Gartner Research DF-14-5486, November 2001.

Gartner (1998). Chinese PC Vendors in Profile, Gartner Research, PCIS-AP-DP-9807, August 1998.

Heeks (1999). Software Strategies in Developing Countries, Working Paper No. 6, Institute for Development Policy and Management, University of Manchester (also published in *Communications of the ACM*).

Huang, W. (1999). Mimeo, National Software and Technology Corporation.

Lovelock, P., Petrazzini, B. and Clark, R. (1997). The Golden Projects: China's National Networking Initiative. *Information Infrastructure and Policy*. 5(4): 265-277.

Lu, Q. (2000). *China's Leap into the Information Age*, Oxford University Press, 2000.

Ministry of Science and Technology of China, 1999 China New-High Tech Industrialization Development Report, Science Publisher, 1999.

NASSCOM (2000). *The IT Software and Services Industry in India: Strategic Review 2000*. New Delhi: NASSCOM.

Schware, R. (1992). "Software Industry Entry Strategies for Developing Countries: A "Walking on Two Legs" Proposition," *World Development*, 20(2): 143-164.

Tan, Z. and Ouwang W. (2002). Global and National Factors Affecting E-commerce Diffusion in China, Research Report, Center for Research on Information Technology and Organizations (CRITO), University of California, Irvine. http://www.crito.uci.edu.

Tschang, F.T. (2001). The Growth and Prospects of the India Software Industry: The Role of Skills and Organizational Capabilities, Working Paper, Asian Development Bank Institute.

Wong, J. and N. S. Ling (2001). *China's Emerging New Economy: The Internet and E-Commerce*. Singapore University Press/World Scientific.