3 China's emerging industrial economy

Insights from the IT industry

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Since the turn of the 21st century, a distinctive Chinese variety of industrial capitalism has taken shape. In this chapter, we trace the contours of China's emergent industrial economy, giving special attention to the role of the information technology (IT) industry. Throughout China's reform era, the IT industry has often been a forerunner of broader trends in the industrial economy, and this continues to be true today. For most of the socialist period, development was equated with large, heavy industrial plants. Even under market transition, the Chinese government at first maintained its faith in guided development and invested resources in large, state-owned firms in the hope of creating "national champions."

However, over the past decade planners have moved away from the "big-is-better" model of industrialization, and instead placed their hopes in science and technology-intensive industry. This focus has recently been formalized in the 11th Five-Year Plan (2006–2010), with its emphasis on human resources, technology development, and a scientific approach to development (Naughton 2005b). The IT industry has thus stepped into the starring role in a long-running drama, that of China's transformation into an industrial economy. We use the IT industry as a wedge to gain entry into the industrial economy as a whole, and to provide insights into the broader development of China's industrial capitalism.

At the same time, we are not just interested in the *context* of IT industry development: we are interested in the changes in business strategy and the building of technological capabilities that are taking place *within* the IT industry. China's industrial economy is already so large and so diverse that it is difficult to make meaningful statements that apply to its entirety. Examining strategy and capabilities – especially innovative capabilities – gives us a crucial benchmark to assess how real the changes in the IT industry have been. What alternative strategies are emerging in China to the now discredited "big-is-better" model? Will China become a leading world technology power? Or will limitations in its economic and innovation system prevent China from moving beyond its current status of a low-cost export-manufacturing platform? In this sense, we assess China's IT industry as an exemplar of China's overall industrial transformation.

From the perspective of the IT sector, we see a fairly successful transition toward a capitalist market economy for China. In the overall industrial economy state ownership is still significant, but it is now concentrated primarily in natural resource sectors and utilities. State-owned firms, while present, play a secondary role in the IT sector, where technical innovation is critical. In fact, China has muddled through to a highly flexible, internationally open, and entrepreneurial solution in sectors such as IT hardware and software.

We therefore disagree with the findings of a pessimistic literature that provides a backward-looking appraisal of weaknesses in China's industrial economy (e.g. Gilboy 2004; Nolan 2002; Rosen 2003; Steinfeld 2004). Rather, we argue that the IT industry has played a crucial role both in transforming China's industrial economy and in forging a peculiar Chinese model of developing a vibrant high-tech industry. A hybrid mixture of ownership and corporate governance patterns has been combined with aggressive policies to foster alliances with global leaders in industry and research. This has enabled Chinese IT firms to accelerate the development of management and innovation capabilities.

The first section of this chapter describes how China's contemporary industrial economy emerged from the state-run economy and introduces our first illustrative case of a Chinese IT company, the computer firm Legend/Lenovo. The next section describes the emergence of a broader three-tiered industrial system, and indicates where Chinese IT companies fit in. The third section highlights new opportunities and challenges for Chinese IT firms that result from their progressive integration into global production and innovation networks. The fourth section introduces Huawei, China's largest telecommunications and networking equipment manufacturer, our second illustrative case. We examine Huawei's business model and show how the company is seeking to exploit the new international division of labor to foster managerial and innovative capabilities.

Prelude: the IT industry's role in creating a market-driven industrial economy

China's contemporary industrial economy emerged from the state-run economy through a process of gradualist transition and incremental marketization. Early on, hundreds of thousands of small, labor-intensive township and village enterprises (TVEs) sprang up under the auspices of local governments. Yet for a long time, Chinese policy-makers also hoped to improve the performance of existing state-owned enterprises (SOEs) and build up large, state-run industrial corporations as "national champions." Chinese planners expected that state-owned firms would be the main force driving the development of more capital-intensive and technologically sophisticated industry.

Consequently, state firms and foreign investors were forced into what were essentially shotgun marriages, with planners serving as match-makers.

This policy was a recipe for lobbying and rent-seeking by existing large state firms, and absorbed an enormous amount of resources. By the mid-1990s, the policy was already in crisis due to its perceived lack of effectiveness (Naughton and Segal 2002). The program suffered a further blow to its underlying rationale when, with the Asian Financial Crisis of 1997–1998, many of the Korean *chaebols* that were a source of inspiration for the program ran into serious trouble. It became apparent to Chinese policy-makers, as to Korean policy-makers, that a fundamental restructuring of the biggest firms would be required.

In this environment, the IT industry provided an attractive alternate model. Many of China's early IT successes were so-called *minban* (civilian) firms. These were firms with lineages in the state sector – and often nominal state ownership. However, these firms had grown up independent of the state industrial hierarchy and enjoyed operational autonomy under the direction of high technology entrepreneurs. Beginning in the 1980s, Chinese policy-makers allowed these firms unusual freedom and flexibility for three reasons: they had observed that small, entrepreneurial start-up firms played a key role in the US's technological resurgence in the 1980s and 1990s (the Silicon Valley model); the new firms were started by individuals with unusually impressive skills and especially good contacts with state research organizations; and finally, policy-makers had few, if any, real alternatives, since none of the large state-owned IT companies offered much promise.

All of these factors were exemplified by the success of a single firm, Legend Computer, later known as Lenovo (Ernst 2006b; Ling 2005; Lu 2000; Xie and White 2004). A start-up in the 1980s, it was a spin-off of the Institute of Computer Science in the elite Chinese Academy of Sciences. An impressive number of such firms sprang up in Zhongguancun, the high-tech neighborhood and later development zone in the northwest of Beijing (near the elite Peking and Tsinghua Universities).

In 1998, Legend became a pioneer in another sense – it became what is arguably the first government-sanctioned management buy-out (MBO) of a state firm. Technically, Legend was an SOE, "owned" by the Chinese Academy of Sciences, which provided the initial personnel and modest financing for its creation. Along with other SOEs after the mid-1990s, Legend was to be "corporatized," which involved explicitly demarcating the corporation's formerly vague and ambiguous ownership stakes.

At this point, Legend's managerial group was essentially the same as its founding group. That this management would gain a substantial stake in Legend was completely defensible: they had created the firm from scratch, and they clearly deserved to reap some of the rewards from their entrepreneurial vision. The managerial group initially proposed that a 38 percent stake of the company be distributed to them, but this ran into an existing government policy that no more than 20 percent of the ownership of an SOE should be distributed to existing employees. After intense negotiations,

Legend employees were allowed to purchase, on highly favorable terms, 30 percent of the company. This compromise enabled the Chinese government to nominally hold on to its existing policy and retain the Academy of Sciences as (passive) majority owner, but give effective control to Legend's founders and managers.

Legend became an important precedent. In subsequent years, MBOs became a powerful channel for the transformation of China's industrial structure. Indeed, for TVEs, management buy-outs, or insider privatizations, had already emerged as an important trend during the 1990s. The Legend restructuring signaled that such procedures could be acceptable in the state sector as well. By the early 2000s, MBOs had become the predominant form of transformation for TVEs and an extremely important – and controversial – mechanism for transforming SOEs as well (Naughton 2005a; Naughton 2007: 286–292, 319–325).

As MBOs gained in legitimacy, privatization became an important force reshaping the Chinese industrial economy. China's industrial system thus went through a profound transformation during the early 2000s. At the top of the industrial hierarchy the central government retained the largest, most important state-owned firms. Meanwhile, at the bottom of the industrial hierarchy, the majority of TVEs and many small SOEs were converted to private ownership. Today's industrial economy therefore emerged from the uneven way in which privatization and restructuring were allowed to spread, forming three distinct tiers of corporations that characterize China's present-day industrial capitalism.

China's emerging industrial economy: a three-tier structure

Tier one

The first tier consists of large, central government controlled firms, which are primarily in sectors with some degree of natural monopoly or market power. In 2002, control of these firms was consolidated in a new body, the State-owned Assets Supervision and Administration Commission (SASAC). Initially, SASAC assumed responsibility for 196 firms, a number that was reduced through merger and consolidation to 159 by the end of 2006 (SASAC 2007). Among this number, there are less than 100 industrial corporations. However, many of the corporations are huge, and one corporation may possess many dozens of subordinate industrial enterprises.

At first glance, this tier of large, centrally controlled firms might appear to exemplify the old "big-is-better" model of industrial organization, but in fact there are considerable differences. The sectoral structure of the centrally controlled firms does not replicate the extremely diversified structure of Korean *chaebols*, or Japanese *keiretsu*. Nearly all the firms in the central "portfolio" have a clear business focus on one or two sectors, often in natural resources. Moreover, these firms have been subject to an ongoing process of restructuring that is frequently designed to get them to focus on "core competencies," that is, on specific sectors in which they have a sustainable competitive advantage.

SASAC's mission is to carry out the state's role *as owner* in the industrial economy. The head of SASAC, Li Rongrong, has repeatedly made it clear that he sees SASAC's mission as increasing the value of government assets. While the central government will share ownership stakes with strategic investors and the public by floating some of the companies on stock markets, the government intends to maintain substantial control.

Ironically, SASAC's interpretation of its mandate has increasingly followed a well-known business school logic: focus on core competencies, spin off noncore businesses. Thus, SASAC has adopted the mantra – first mooted by General Electric – that a company should be number one, two, or three in its business. Otherwise, it should get out. The key slogan, then, is "focus," not "big-is-better."

In addition, most of the centrally controlled firms are in sectors where there is a degree of market power. They control the key natural resource, telecom, and trading companies. In 2006, central SASAC's firms produced profit and turned over taxes equaling an enormous 6.8 percent of GDP, evidence of their market power (SASAC 2007). In fact, SASAC's newly important role increases an emphasis on maximizing monopoly rents. Every capitalist would like to have a monopoly position: SASAC is no different. Because SASAC's role is to represent the government *as owner*, it naturally stresses financial returns and puts less emphasis on economic growth, economic reform, and fair competition (roles performed by government regulatory agencies and the National Development and Reform Commission).

The large central government firms that are most important to the IT industry are the telecom operators. As of 2006, four large telecom firms are subordinate to the central government. Three of these were spun off from the old government monopoly service provider: China Telecom (fixed line); China Mobile; and China Netcom (a combine of fixed line and internet backbone services). A new entrant, China Unicom, with a totally different – but still state-owned – background was allowed to provide competing mobile services. All of these firms are predominantly state-owned, and SASAC now "owns" all four. As a result, SASAC seeks to moderate competition among them in order to create a viable combination of healthy firms, tacit collaboration, and high profits.

This objective was particularly in evidence in October 2004 when SASAC shuffled the management of the top three telecom firms, replacing the top manager in each firm with the second or third-rank manager from a competing firm. The message was clear: don't compete too aggressively, for the company you compete with could one day be your own. SASAC's intervention is ongoing: throughout 2005 and 2006, SASAC struggled with different proposals to reorganize the telecom industry, looking for ways to

shuffle activities and licenses among operators in order to create stronger, competitive companies that will adopt advanced "third generation" (3G) telecommunications technology.

While SASAC has obviously been looking for ways to support a domestically grown 3G telecom standard (known as TD-SCDMA), it has had trouble finding an effective policy in this market environment. All of the existing telecom firms would like to move into 3G mobile telephony, but none of them wants to be saddled with the unproven domestic standard. In all four cases, the telecom companies have complex corporate structures with minority shareholders inside and outside China, so SASAC is not able to simply redistribute assets (and licenses) among the groups as it could have in the old days.

The dynamics of the telecom industry are very important for China's IT hardware industry, because the service providers are big customers. Choices about technological standards, domestic preferences, and business rules shape the options of the hardware industry. Precisely because the service providers have some market power, they have rich margins that allow them to pay higher costs to support fledgling companies and new initiatives. The telecom firms are not themselves likely to be the cutting edge firms of China's technological future, but they will provide opportunities for other companies that may play dynamic roles.

Several IT hardware companies do show up in SASAC's portfolio, and each has a unique history in the state sector. The first, China Electronics Technology Corporation (CETC), is a grab-bag of forty six research institutes, part of the military industrial complex, but with a number of subordinate profit-making companies as well.[1] The second, China Electronics Corporation (CEC), descended from the firms controlled by the Ministry of Electronics and today groups together sixteen wholly owned subsidiaries and thirty controlled companies. The third, Putian, groups together the telecommunications equipment factories that used to be subordinate to the Ministry of Post and Telecommunications.

Some of the firms subordinate to these three big groups have significant independent capabilities. However, each of these groups is in fact a fairly troubled jumble of companies. The subordinate companies of each seek to establish themselves independently, a feasible objective since ownership of the companies is often shared among state and nonstate groups. Meanwhile, the groups themselves are subject to continuous reorganization. For instance, one formerly independent firm, Great Wall Computer (best known for its joint venture with IBM) was merged into CEC on August 1, 2005 (SASAC 2005).

Two other IT hardware firms show up in SASAC's portfolio. One is a joint venture in Shanghai with Alcatel, "centrally controlled" by historical accident: this is arguably the only successful example of a planner-orchestrated partnership involving foreign multinationals (Mu and Lee 2005; Shen 1999). The final IT firm, IRICO, is a color picture-tube producer near Xi'an, legacy of an earlier stage of China's development.

It is most striking what we do *not* observe in this portfolio of central government IT firms. Unlike the robust, wealthy, and centrally managed large firms in the natural resources, energy, and public utility fields, we do not find in this portfolio a single potential "national champion." SASAC's IT firms are unstable groupings with wildly varying capabilities. With a few exceptions, the most dynamic hardware and software companies are not under SASAC, but rather in China's second tier of companies.

Tier two

The second tier of industrial firms is made up of medium-sized firms operating in competitive markets. Second-tier firms have diverse origins: they may come from the state sector, from foreign investment, or, increasingly, may be domestic Chinese start-ups. Firms that originated in the state sector were usually local government-controlled. Since they were rarely in monopoly sectors, they were exposed to competition and less profitable than central government firms. No strategic rationale thus existed for public ownership and local governments were quite willing to privatize or close down these firms (Li and Lui 2004). As noted above, MBOs have been permitted after 2000 in small- and medium-sized state firms. These firms are now rapidly restructuring and privatizing, creating one of the seedbeds of the new production forces and new interest groups shaping China's emergent capitalism.

As a result of the new flexibility about ownership, hybrid firms are rapidly being created. These firms take on a variety of organizational forms, particularly in the IT sector. There is no single hybrid pattern, but we can identify three characteristics that are often present. First, there is often a dominant manager or managerial group, usually with a significant ownership stake. These firms move quickly because they have personalized decisive leadership; they are not yet bureaucratized companies.

Second, ownership is divided. These firms are usually not 100 percent privately owned. Local governments often hold minority stakes, either directly, or through intermediaries. When these firms are listed on the stock markets, a minority of shares is typically sold. Companies from Hong Kong, Taiwan, and overseas often hold stakes as well. Shared ownership seems to be commonly used to align interests between entrepreneurs and other stakeholders, including local government.

Third, many of these firms are linked to overseas actors through global production and innovation networks. Multiple forms of integration, such as contract manufacturing (in both directions), research partnerships, licensing, equity stakes, and many other means connect domestic with foreign firms (Ernst 2007).

This is the most dynamic part of Chinese industry today. Released from state control, powerful local interest groups are supporting the emergence of new companies, frequently in collaboration with foreign firms. With China's

booming economy and its large pool of knowledge workers providing ample opportunities, this segment of industry is undergoing explosive growth and defining the future of Chinese capitalism. Flexibility is the byword, and in many cases it is simply no longer possible to classify firms into the old categories of state-owned, collective, private, or foreign-invested. Some industrial sectors straddle the first and second tiers: for example, steel and automobiles. Large state-owned companies still dominate, but rapidly growing hybrid, mostly private firms with local government backing, are emerging to challenge the leaders.

The steel industry is a good example. State control in this capital-intensive industry was traditionally reinforced by the state's privileged access to financing. But today private firms are growing explosively, especially in Hebei, Jiangsu, and Zhejiang. It is still not entirely clear whether the central government will allow genuine competition between its firms and newly entering private steel companies. In July 2005, the central government promulgated an official industrial policy for the steel industry (National Development and Reform Commission 2005) that clearly intends to shore up the state's position. Foreign companies were forbidden to purchase controlling stakes, but domestic private interests were not. A guess based on China's past trajectory would say that sectors such as steel and automobiles – unlike oil, electricity, and telecom – will within five to ten years be dominated by large hybrid businesses, and fall clearly within the second tier of Chinese industrial firms.

China's IT industry is predominantly in the second tier, since the most important and most dynamic firms are hybrid firms. As we argue in more detail below, the global IT industry is being transformed by an increasing vertical specialization of production – "modularity" of organization is extended across all stages of the value chain, including research and product development. To adjust to the resultant rapid changes in technology and markets, Chinese IT firms require robust innovation and management capabilities and a high degree of flexibility.

Legend/Lenovo Computer demonstrates the importance of strategic flexibility. The company started out primarily as a reseller of foreign computers, and gradually moved into assembly. Its founder espoused a model he dubbed "*mao-gong-ji*," or moving from trade, through manufacturing, to technology development. Contrary to much that has been written, Lenovo never really developed into a manufacturing powerhouse. Instead, it developed a strong domestic brand and good design, distribution, and supply networks. For example, in 2003, Lenovo outsourced 100 percent of its laptops and 40 percent of its motherboards to Taiwan contract manufacturers, thus turning the "international subcontracting" model on its head (Jiang 2004).

Lenovo's subsequent, highly publicized acquisition of IBM's personal computer division built on this foundation to create the ultimate hybrid firm. As part of its acquisition of IBM in late 2004, Lenovo received a US$350 million private equity commitment from Texas Pacific Group, General Atlantic, and Newbridge. These new investors have reduced IBM's share in Lenovo to 13.4 percent and hold around 12.4 percent of Lenovo's capital. As a result, private equity investors are now involved in much of Lenovo's decision-making (Ernst 2007).

Lenovo's headquarters moved to the US, and the company announced it would adopt English as its official language. In fact, the company hired an American, Bill Amelio, as CEO, an executive who had previously been in charge of Dell Computer's Asia operations. By this choice, Lenovo showed that it believed the ability to manage complex multinational supply networks would be the critical success factor.

Therefore, in the course of its multiple transformations, Lenovo has come to exemplify the "hybrid ownership" that is so distinctive a feature of China's second tier of industry. Like Lenovo, most of the leading Chinese IT firms – Hai'er, TCL, Founder, Huawei, ZTE, Datang, and SMIC – can be accurately characterized as hybrid firms with substantial public and private ownership stakes.

Tier three

The small-scale sector, which forms the third tier, has undergone important changes as well. TVEs have themselves become almost entirely privatized; and their ties with local communities have weakened. The resulting small-scale sector has much more flexible labor markets, and a strong tendency towards industrial clusters and flexible specialization. These industrial clusters – often characterized by hundreds of small firms competing and collaborating – have grown up to serve export markets in sectors of both high and low technology. The town of Zhuji, in Zhejiang, produces 35 percent of world sock output – 8 billion pairs a year – almost entirely from small- and medium-sized enterprises. Another Zhejiang town has hundreds of small electric hand tool component producers and assemblers (Qian 2003; Ross 2004). Thus, openness and flexible specialization is an increasingly important characteristic of China's small-scale sector.

The bulk of the third tier is in relatively low technology, labor-intensive production, but the dividing line between primitive and sophisticated technology is not as clear as it once was. It is no longer the case that small-scale necessarily means low-technology, primitive, backward family firms. Relatively sophisticated industrial sectors now include clusters of small high-tech firms, often linked by subcontracting networks. These can be alternatives to larger firms. When flexible specialization and high technology come together, the result is a cluster like the one around Dongguan, in Guangdong's Pearl River Delta. More than 95 percent of the components of a desktop computer are produced within a 50-mile radius of Dongguan. Most of this production is from foreign-invested firms, but small-scale firms play important roles as suppliers (Huang 2002).

The transformation of the small-scale sector now extends beyond manufacturing, and includes product development and some aspects of applied research. Good examples are Celestial Semiconductor, a start-up company in the Shangdi Information Industrial Base in Beijing's Haidian District that specializes in mixed-signal chip design, as well as Tech-Faith, a firm that recently listed on NASDAQ and specializes in the design of mobile phones. Both are cases of dividing the value chain into increasingly narrow slices that now also include innovation (Ernst 2006a, 2006b).

Opportunities and challenges for Chinese IT firms

Why is flexibility and international openness so important for China's development trajectory? China's opportunities to develop its IT industry differ from those faced earlier by Japan, Taiwan, and South Korea. China has a unique combination of competitive advantages that shape the context in which its IT industry develops. First and foremost, China has a huge and booming market for electronics products and services. Second, China has the world's largest pool of low-cost specialized and easily retrainable labor. Third, deriving from the two previous factors, China has recently seen the emergence of sophisticated lead users and test-bed markets, giving it new opportunities in the area of innovation. Finally, Chinese policymakers can learn from the past achievements and mistakes of their East Asian predecessors to adjust national and local policies.

At the same time, the global environment within which China seeks to develop is dramatically different from that of previous East Asian success stories. Most importantly, China's technological development over the past twenty years has been inseparable from the expansion of global production networks (GPNs) and the relocation of most production stages, including engineering and R&D. China is far more integrated into these networks than were Japan and South Korea earlier.

Incoming foreign direct investment has averaged over 4 percent of GDP in China over the past decade; during Japan and South Korea's high growth period, incoming foreign direct investment was never as much as 0.5 percent of GDP. It is thus about ten times as important in China as in these earlier developers, and nowhere more so than in high technology exporting. In 2005, foreign-invested enterprises produced 58 percent of China's total exports, but fully 88 percent of high-technology exports (Ministry of Commerce 2006). As a result, China's emerging industrial economy in the IT industry cannot be meaningfully assessed except in the context of the GPNs into which Chinese firms are increasingly integrated.

The ability of Chinese manufacturers to participate in GPNs provides valuable opportunities, but also creates new challenges. GPNs are usually organized by global "flagship" firms, who seek to structure them in their own economic interest (Ernst 2002). They have an important element of hierarchy: flagship firms serve as overall architects, and they prefer to define platforms and maintain strategic control to reap rents, while

outsourcing as much low cost activity as possible to China. These incentives are at work both in production networks and in innovation networks.

The trend of "innovation offshoring" (Ernst 2006a) has given rise to global innovation networks (GINs) that global corporations are gradually grafting onto their existing GPNs. Both GINs and GPNs are complex and multilayered "networks of networks" that involve both global corporations and "local" companies, that is, East Asian companies that are focused primarily on the region. GINs share two defining characteristics with GPNs: asymmetry, because flagships dominate control over network resources and decision-making; and knowledge diffusion, because the sharing of knowledge is the necessary glue that keeps these networks growing. In fact, the hierarchical nature of flagship-dominated networks appears to facilitate knowledge exchange (Ernst and Kim 2002), and hence provides new opportunities for Chinese IT firms.

Practically all global IT industry leaders, as well as a growing number of second-tier firms, have begun to conduct R&D in China. Increasingly, the focus is shifting from the adjustment of existing technologies to the development of new products and processes dedicated to the Asian market (Armbrecht 2003). In addition, China's "brain drain" has produced transnational skilled migrant communities that can act as highly effective carriers of tacit knowledge about global market and technology trends.

On balance, these global transformations create substantial new opportunities for Chinese IT firms. The cost advantages of China's deep and relatively sophisticated manpower base are well documented (e.g. Banister 2005). Less fully recognized has been the extent to which the Chinese market, in addition to its sheer size, provides many of the advantages of a lead market (Beise 2004). In addition, China's deep integration into GPNs and GINs arguably facilitates knowledge diffusion and exports. The most significant strategies will therefore be those that allow firms to benefit from China's unique combination of competitive advantages: low labor costs for unskilled and some highly skilled workers; large and growing markets for IT products and services; and "openness" to international trade, investment, and technology (Liu 2005).

Pessimistic analysts of Chinese capabilities focus on the limited roles Chinese firms have initially played within GPNs. They argue that integration into GPNs will lead, at most, to gradual improvements of operational and manufacturing capabilities, leaving Chinese firms stuck at the bottom of innovative capabilities. This misses the driving force of creative opportunism which leads Chinese firms to focus on cheaper, simpler products tailored to the Chinese market. These can be profoundly "disruptive" even though initially not seeming to be technologically impressive.

To establish what options are realistic, we draw on two analytic tools: a well-known taxonomy of innovation (see Table 3.1) that distinguishes "incremental," "modular," "architectural," and "radical" innovations (Henderson and Clark 1990); and the concept of "disruptive technologies" (Christensen 1997). "Incremental" innovations take both the dominant component design and architecture for granted, but improve on cost, time-to-market,

Table 3.1 Typology of innovations

Architecture \ Components	unchanged	changed
changed	architectural	radical
unchanged	incremental	modular

Source: Adapted from Henderson and Clark (1990).

and performance. With "modular" innovation, new component technology is plugged into a system architecture that is fundamentally unchanged. This type of innovation has been a defining characteristic of the personal computer industry; for instance, the multifunctional USB port on the personal computer exemplifies modular innovation.

"Architectural" innovations change the way components are designed to work together, but use existing component technology that is available on the market to implement new designs. Architectural innovations thus introduce substantially new and distinct features to existing system architectures. They also build on a company's familiarity with market demands, as with the development of Chinese-language electronics publishing systems by the Founder Group Company, a spin-off from Peking University (Lu 2000).

Finally, "radical" innovations involve both the use of new component technology and changes in architectural design. They typically involve breakthroughs in both areas, such as the invention of the Internet. These innovations receive the greatest attention, and high margins through premium pricing and strong market entry deterrents. However, radical innovations require an extremely broad base of capabilities, and involve huge risks. They are beyond the reach of most IT companies in China.

Christensen (1993) argues that established, vertically integrated market leaders typically lead in the adoption of new component technology, while successful new entrants rely on architectural innovations. Technological complexity, and hence risk and cost, are lower for architectural innovations than for the development of new components, and architectural innovations lead more immediately to increased sales and profitability. Christensen's (1997) concept of "disruptive technologies" deepens our understanding of these market factors.

Disruptive technologies bring to market very different products: they have features that initially only few new customers value. Products based

on disruptive technologies are typically cheaper, simpler, smaller, and, frequently, more convenient to use. Incumbent firms, especially market leaders, generally fail to notice "lower-end" markets that may erode their market leadership. That is because they promise lower margins, their most profitable customers generally do not want products based on disruptive technologies, and the required break from routine requires a different organization from sustaining technologies. Most importantly, developing disruptive technologies requires an organization of innovation with substantially lower overheads.

Chinese IT firms are more likely to produce important innovations that are architectural or incremental, rather than modular or radical. The ability of Chinese IT firms to profit from architectural innovation may seem counter-intuitive, but it follows from their growing integration into GPNs and GINs, and their familiarity with peculiar features of Chinese markets. Chinese firms face relatively low entry barriers for "disruptive" technologies, while they can leverage participation in GPNs and GINs to buy in widely available existing component technology. Chinese IT firms thus will often pursue architectural innovations leading to disruptive technologies.

There is also scope for substantial incremental innovation by Chinese IT firms. To stay in the GPNs, Chinese firms must improve on cost, time-to-market, and performance. Intensifying price competition, especially in the China market, implies that Chinese firms are under tremendous pressure to exploit such incremental innovations across all stages of the value chain. These small incremental innovations gradually add up and may in time shift the rules of global production and innovation activities (Ernst 2007).

By contrast, the focus in much of the current literature on China's technology effort has been on Chinese government attempts to create national champions and mandate technical standards (Linden 2004; Suttmeier and Yao 2004). The Chinese government focuses on core "strategic" technologies ("radical" in the terminology we have used here), while its policies are interventionist, certainly more so than India's. China's ambitious government efforts have caused worries that Chinese firms could successfully create "radical" innovations (US-China Economic and Security Review Commission 2005), while the extremely modest rate of success feeds the technological pessimism described above.

We argue that these areas are simply not likely to be where the action is. Innovative firms trolling through the global knowledge base and opportunistically creating new architectural solutions to new market demands are the more likely seedbeds of technological breakthroughs. As for the Chinese government, it has overall done a reasonably good job of not intervening too much in firm decision-making, while providing a degree of unconditional resource support. It has displayed a healthy respect for the accumulated knowledge base possessed by global corporations, and policy makers have in recent years primarily focused on moving up the value chain within the context of GPN's.

Chinese IT firms responding – the case of Huawei

Incorporated in 1988 and based in Shenzhen, Huawei is China's largest telecommunications and networking equipment manufacturer.[2] Huawei has experienced rapid growth of sales and profits, registering 25 percent annual sales growth since 1998. The company is also a telling example of the hybrid mixture of ownership and corporate governance that is a defining characteristic of China's second-tier industrial companies. In legal terms, Huawei is a "private" company, but it is not listed on any major stock exchange, and hence is not included in the *Fortune* list of "China's 100 Largest Companies."

The real driving force is Ren Zengfei, a People's Liberation Army veteran, who founded the company and who, as the company's president and CEO, exerts strong and idiosyncratic managerial influence throughout the organization. The company has a reputation for secretiveness, somewhat murky corporate governance, and top-down management by command and extensive micro-management. Employees hold the majority of Huawei "inner" shares, which arguably reflects the critical role the company has assigned to its highly skilled workforce – 90 percent of its 30,000 employees worldwide hold bachelor's degrees or higher.

Within a few years, Huawei has been able to establish itself as a serious new competitor in the telecommunications industry. The company's success owes much to its focus on being a "low-cost cloner," seeking to price its products 30 percent lower than global market leaders. In addition, Huawei offers very aggressive sales incentives and exhaustive after-sales services, and it has a good reputation in customizing system engineering to specific requirements of customers who require "no-frill" systems. This business model was well in line with Huawei's initial strategic focus – to penetrate the Chinese market as well as secondary overseas markets in developing Asia, Africa, Latin America, and Eastern Europe.

However, the company is now seeking to expand its geographical presence and to upgrade its product line. It is forced to do so in order to counter aggressive attacks by its main global competitors, who are gaining market share in China.[3] Huawei's aggressive plans for overseas expansion project a fivefold increase in international sales from US$2.28 billion in 2004 to around US$10 billion by 2008. In order to achieve this ambitious goal, the initial focus on secondary markets in developing and transition economies now needs to give way to a substantial expansion in the critical markets of the US, Europe, and Japan. Some initial success stories have been widely quoted in the press. These include British Telecom's decision to include Huawei in its list of eight preferred suppliers for the overhaul of its UK fixed-line phone network; and the decision by Telfort, the Dutch mobile operator, to contract Huawei to build its 3G mobile phone network. In fact, Telfort passed up an offer from Ericsson, its main supplier since 1998.

This is just the beginning of a very long road. To penetrate the world's most sophisticated markets, Huawei now seeks to transform itself from a "low-cost cloner" to a provider of integrated and customized network solutions and services. While fixed-line networks of telecommunications equipment still provide the bulk of revenues, mobile and optical networks are providing the fastest revenue growth. In addition, the company has committed substantial resources to develop value-added communication services and mobile handsets, especially for 3G mobile communication systems. Huawei has continuously invested more than 10 percent of its revenues in R&D. According to the company website (July 29, 2005), Huawei has applied for 6,500 patents, and been granted 1,400 already. After initially earning a bad reputation on intellectual property rights infringement (Einhorn 2004), the company now claims to follow a strategy of stringent protection.

The focus of Huawei's innovation efforts is on a judicious combination of incremental and architectural innovations that provide integrated solutions throughout the life cycle of communications systems. In terms of incremental innovations, Huawei has made a conscious effort to improve on cost, time-to-market, and performance across its product range. This includes, for instance, substantial improvements in the management of product development, quality control, supply chains, and customer relations.

Building on the company's familiarity with market trends and user requirements of operators in developing countries, Huawei has also pursued architectural innovations. It has developed equipment and solution packages that, while under-performing relative to established products in mainstream markets, satisfy the essential needs of operators at much lower cost. An example is "Tel@com," Huawei's patented approach to the alignment of existing fixed networks that allows operators with limited budgets to adjust quickly to and exploit the rapid development of IP (internet protocol) telephony and broadband technologies. Another example is a distributed 3G base station that needs no special equipment room, thus dispensing with costly rental, and which has only two thirds of the average power consumption of similar products in the industry.

Such strategies may now be increasingly effective in the leading telecommunications markets of industrialized countries. After the bursting of the telecommunications bubble in 2000, and the resultant turmoil and wealth destruction, leading telecom operators are much less willing than before to buy the overengineered and very expensive equipment, systems, and services that are on offer from global industry leaders. In short, the overriding objective of Huawei's strategy to upgrade its product portfolio is to provide "integrated communication and network solutions . . . in order to consistently create maximum value for customers," especially those with limited budgets (Huawei Annual Report 2004: 11).

Huawei exemplifies an important characteristic of Chinese IT companies by forging collaborative agreements and alliances with global industry

leaders and universities. Huawei, for instance, relied heavily on IBM's consulting arm to develop sophisticated "integrated product development" techniques, and foster Huawei's "integrated supply chain" management. Through its software development affiliate in Bangalore (India), Huawei became familiar with the huge efficiency gains to be reaped from state-of-the-art project management techniques. In cooperation with Carnegie Mellon University, the company's four software development divisions (in Shenzhen, Bangalore, Shanghai, and Nanjing) have all been awarded CMM5 certificates, the highest level of software project management certification.

As for quality control and production flow management, Huawei has heavily relied on Germany's Fraunhofer Gesellschaft, including integrated production line layout and warehouse automation, thus reducing material movement, shortening the production cycle, and improving production efficiency and quality. Global consulting firms (especially KPMG and IBM) have also played an important role in developing key elements for implementing Huawei's move from an equipment supplier to a provider of integrated solutions. Most importantly, Huawei has spent substantial efforts in upgrading its human resource management practices in cooperation with global consulting firms, such as Hay and Mercer. These actions helped the company to improve staff recruitment and development. One positive indicator is that Huawei has been ranked as number five in the July 2005 list of "Best Chinese Students Employer Award," published by ChinaHR.com.[4]

Like other Chinese IT companies, Huawei's initial key competitive advantage was the low cost of its researchers and engineers. Out of its worldwide workforce of about 30,000, over 14,500 (48 percent) work in R&D. More than 6,000 of this R&D workforce are specializing in 3G and related technologies. Most of the R&D personnel are now based in China, where salaries typically are one third to one fifth of US salaries (Ernst 2007). The low cost of R&D personnel explains how Huawei can develop tailor-made solutions that address the specific needs of network operators with tight budgets.

As in other East Asian exporting countries, demographic trends in China will, over the longer-term, slow the growth of the working-age population, creating pressures for wage increases. One of the by-products of the one-child policy in China is that labor force growth will slow dramatically after 2015. Indeed, this is one of the biggest differences between China and India: India is one of the few countries with significant technological capabilities in which the working-age population is poised to grow for the next forty years, keeping wages low.

It will take time before the current huge wage cost differentials between China and industrialized countries will be reduced, but the erosion of labor cost advantages is already a reality for highly skilled labor in the IT industry. In both China and India, IT firms complain about a

Table 3.2 Huawei's global innovation network

Kristal/Stockholm, Sweden	Base station architecture and system design; analog-mixed signal design (RF); algorithms
Moscow, Russia	Algorithms; RF design
Bangalore, India	Development of embedded SW and platforms
Plano, Texas (Dallas Telecom Corridor)	Total solutions for CDMA; G3 UMTS; CDMA Mobile Intelligent Networks; mobile data service; optical; voice over Internet protocol

Source: © Dieter Ernst.

severe shortage of experienced engineers and managers, which is driving salaries up and creating a "war for talent" (Ernst 2006a). As jobs become more senior and require greater expertise and experience, pay increases cost proportionately much more in China than in the US. Thus, while China's supply of current engineering graduates exceeds that of any other country, there is a shortage of experienced and highly qualified engineers and scientists.

To overcome this critical shortage of senior and experienced engineers and managers, Huawei has pursued a two-pronged strategy: it is building a variety of linkages and alliances with leading global industry players and universities, while concurrently establishing its own global innovation network. Huawei has thus developed a web of project-specific collaboration arrangements with major suppliers of core components, such as Siemens (as part of China's TD-SCDMA project), 3Com (with a focus on sales and joint product development), as well as Intel and Qualcomm. Huawei's emerging global innovation network now includes, in addition to six R&D centers in China, four major overseas R&D centers (see Table 3.2).

In sum, Huawei displays all the characteristics of a company that is building impressive and genuine technological capabilities. There is no guarantee that Huawei will continue to grow, nor can we predict how many firms like Huawei will ultimately emerge in China. However, this particular case study supports the general picture of openness, flexibility, and technological dynamism which we painted in more general terms in earlier sections.

Conclusion

This chapter presents an optimistic picture of China's industrial development, as seen through the perspective of the IT industry. Both Chinese domestic factors and international economic trends have contributed to the rapid restructuring of the Chinese IT industry into a highly dynamic,

flexible, and open structure. The diversity of Chinese industry is its great strength. Equally important are flexibility and international openness that have enabled Chinese IT firms to take advantage of the new opportunities that result from transformations in global production and innovation networks. This has enabled Chinese IT firms to accelerate the development of management and innovation capabilities.

In this context, we should not overestimate the state's role in Chinese industry. Although government policies are pervasive and specific interventions common, the most important activity with respect to the IT industry is not in the government sector at all, but in the second-tier hybrid sector. State ownership is significant in industry overall, and is likely to remain so for the foreseeable future. But state ownership is increasingly circumscribed in areas where it is probably not terribly costly economically, and may even have some justification in providing public goods and social services. The most dynamic sectors are evolving in different directions.

China is developing a multi-centric economy with great local diversity. In a broad sense, we are seeing a shift in the locus of technological dynamism beyond Beijing, and toward the Yangtze Delta (especially), as well as the Pearl River Delta. In the recent wave of technological dynamism, Beijing's Zhongguancun has displayed nowhere near the creativity, or dominance, that it displayed in the earlier, 1990s wave. New centers of semiconductor production and design, software, and new web-based services are growing up outside of Beijing.

In a related fashion, the rapid emergence of industrial clusters, composed primarily of small firms, is reshaping the distribution of both traditional and high-tech industries. This seems to represent the reemergence of a pattern with deep roots in Chinese history and culture. There are many precedents in China for dense networks of competing and cooperating small firms. As this pattern deepens, we expect to see increasing differences in the composition of output across different geographical regions.

We may speculate that this pattern has long-run political implications as well, and may influence the political evolution of China. Firms at both the central and regional levels continue to be characterized by close government-business ties, hybrid ownership, and insider dealing. This characteristic will combine with patterns of regional differentiation to create regional interest groups. It is not far-fetched to expect that region-based interest groups will create the first patterns of open political competition in China. Indeed, perhaps this is already happening, as Beijing politicians seek alliances in the Northeast and West to offset the growing economic clout of the Southeastern provinces.

Our most important conclusion concerns the IT industry itself. Close examination of that industry reveals patterns of organizational and strategic behavior that are likely to foster robust development. Moreover, this is coming at a particular stage in the process of globalization that is enabling new kinds of cross-border cooperation at a deeper level, extending beyond

production to design, development, and research. All these activities have economic implications: there is a great deal of successful development of capabilities and transfer of technology as part of these international networks of cooperation and competition. As a result, we expect the IT industry to continue to thrive and provide a powerful impetus to the continuing of China's capitalist transition.

Notes

1 Overall, at least 15 other firms in the SASAC portfolio come from the military industrial complex.
2 This section draws on a detailed case study in Ernst (2006c).
3 These include Alcatel and Lucent for telecom equipment, and Cisco and Juniper for enterprise networking equipment.
4 The survey was conducted among 27,000 recent graduates of 600 Chinese universities. The 2005 ranking is Haier, IBM, P&G, Lenovo, Huawei, China Mobile, Microsoft, Siemens, LG, and GE.

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