TERESA SHUK-CHING POON

# UPGRADING THE INFORMATION COMMUNICATION AND TECHNOLOGY INDUSTRY IN CHINA: A GLOBAL VALUE CHAIN ANALYSIS[1]

Using the global value chain (GVC) perspective, this article examines the upgrading trajectory of the information communication and technology (ICT) industry in China. It argues that Chinese firms operate in technological and institutional contexts that have enabled the adoption of a model of industrial upgrading unique to China as a large and late developing country. Such a model of industrial upgrading is facilitated by China's huge and booming domestic market, culturally obscure to lead firms in advanced industrialised countries due to the relative lack of knowledge of local consumer preferences and requirements—as well as of the characteristics of domestic markets and institutions. In contrast, Chinese manufacturers of ICT products and providers of ICT services are able to offer architectural and incremental innovations that satisfy the local consumers' demand for less sophisticated products and services at more affordable prices. This article concludes by drawing some theoretical implications for the GVC perspective.

There is a growing body of literature examining the intricate relationships among globalisation, inter-firm linkages, and industrial upgrading. One important strand of this literature is the global value chain (GVC) perspective, which sets out to examine how firms in developed and less developed countries link to create and capture the relative value embedded in various economic activities carried out to generate end products and services. In examining the process of industrial upgrading in less developed countries, the GVC perspective explains the ways in which dispersed production and distribution systems are globally integrated, and how firms in developing countries—small- and medium-sized enterprises (SMEs), in particular—may enter into and capture the higher-value added activities of the GVCs (Gereffi 1994; Gereffi 1999; Gereffi et al. 2001; Gereffi, Humphrey, and Sturgeon 2005).

Using the information communication and technology (ICT) industry in China as a case study, this article argues that the specific technological and institutional contexts in which Chinese firms operate have enabled the adoption of a model of industrial upgrading different from that developed earlier in

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smaller economies. Such a model of industrial upgrading is facilitated by the country's huge and booming domestic market for less sophisticated products and services—Chinese firms are able to capture this market by producing architecturally or incrementally innovative goods and services at affordable prices. Its dynamic nature and extensive linkages to other industrial sectors make the ICT industry a good case for examining the usefulness of the GVC perspective in explaining the trajectory of industrial upgrading. The information used in this article is mainly collected from secondary sources.

This article contains five sections. Following this short introduction, the second section describes briefly how the GVC perspective explains the process of industrial upgrading in developing economies. The third section examines the development of the ICT industry in China over the past 25 years. The fourth section analyses the upgrading trajectory and model of the ICT industry. Finally, the fifth section concludes this article with a discussion of the theoretical implications.

## GVCs and industrial upgrading

The GVC perspective has its foundations in the global commodity chain (GCC) approach, which focuses on mapping the internal governance of commodity chains containing various economic roles with different proportions of value added. With an increasing degree of globalisation and technological advancement fuelling further disintegration of the value chains, these economic roles are performed by a diverse range of firms located in different countries. The GCC perspective examines how lead firms—usually located in advanced industrialised countries—shape and control the development of commodity chains containing various economic roles with different proportions of value added assumed by economic actors located in various countries (Gereffi 1994; Gereffi and Korzeniewicz 1994; Gereffi 1999). The term 'global value chain' has been introduced to de-emphasise the limiting connotations of the word 'commodity' in 'global commodity chain', which—to many—means undifferentiated products with low barriers to entry. In contrast, the word 'value' in 'global value chain' highlights the importance of relative value creation and value capture by firms engaged in economic chains (Gereffi et al. 2001; Gereffi, Humphrey, and Sturgeon 2005).

A GVC denotes the economic activities carried out to bring a good or service from its conception—through production, marketing, and distribution—to the final provision of customer service and support. The GVC perspective examines how production and distribution systems are integrated globally, and what the consequences for firms in developing countries involved in GVCs are in terms of access to global markets, upgrading opportunities, profitability, and employment. For firms in developing countries, access to markets in developed countries has become increasingly dependent on participation in GVCs controlled by lead firms based in developed countries—to close the technological gap gradually and upgrade successfully, firms in developing countries need to link with and learn from firms based in developed countries (Gereffi, Humphrey, and Sturgeon 2005).

From a GVC perspective, industrial upgrading represents the acquisition of technological capabilities and market linkages that enable firms to improve their competitiveness and engage in higher-value activities. From product or service conception to final use, firms in less developed countries can upgrade industrially by linking with lead firms based in more developed economies in different ways. There are basically four different kinds of industrial upgrading. First, firms in less developed countries have achieved *process upgrading*, if they reorganise the production systems and transform inputs into outputs more efficiently. Second, firms in less developed countries have achieved *product upgrading*, if they move into manufacturing more sophisticated lines of products. Third, firms in less developed countries have achieved *functional upgrading*, if they increase the overall skill content of various activities and successfully acquire new functions—for example, to move from assembly to original equipment manufacturing (OEM), to original design and manufacturing (ODM), and then to original brand manufacturing (OBM). Finally, fourth, firms in less developed countries have achieved *inter-sectoral upgrading*, if they use the knowledge acquired in particular chain functions to move horizontally into different industrial sectors.

The successful industrial development of Taiwan over the past few decades illustrates well the usefulness of the GVC perspective in explaining the industrial upgrading of less developed economies. Since the 1970s, Taiwanese firms—mainly SMEs—have gradually improved their technological capabilities through technology transfer and knowledge diffusion by hooking onto various GVCs as OEMs and ODMs for multinational corporations of developed countries. They started by picking up simple assembly skills and developing incremental process capabilities to control quality and the speed of production. Once full production skills were acquired, these Taiwanese suppliers became involved in product design, quality control, process engineering, and innovation.

Finally, they engaged in both product and process research and development (R&D) of the more mature commodities (Hobday 1995). Various types and levels of technological knowledge and skills absorbed by first-tier Taiwanese suppliers were diffused to smaller local subcontracting firms operating in the same GVCs. Consequently, entering from the mature phase of the product lifecycles, Taiwanese firms learned their way from the standardised later stages of technological development to the more uncertain—design-intensive and design-complex—earlier stages that demanded more innovation. Gradually, with each new wave of product innovations, Taiwanese suppliers for global lead firms became involved in the activities associated with the early stages of the product lifecycles, closing the technology gap with the global multinational firms incrementally—this process enabled both product and process upgrading. Some of the more established Taiwanese firms achieved functional upgrading by moving beyond OEM and ODM and engaging in OBM, selling and distributing products bearing their own brands. This played an important role in fostering the development of local entrepreneurship and a higher degree of domestic industrial integration. Fuelled by an increasing domestic demand for upstream components and downstream applications, some Taiwanese firms ventured beyond producing basic components and low-end products and into manufacturing more advanced products and critical components in related upstream and downstream sectors, achieving inter-sectoral upgrading in the process.

## The development of the ICT industry in China

The early development of the ICT industry in China was associated with the development of the consumer electronics industry, which was promoted by the Chinese government in the early 1980s to stimulate the production of electronics components and integrated circuits. It was the original intention of the Chinese government to drive the development of the ICT industry using large state-owned enterprises (SOEs). In the early 1990s, the Chinese government attempted to develop SOEs into large ‘national champions’ that could compete with foreign multinationals. In 1993, the government formally announced the implementation of the big business strategy, merging existing SOEs across sectors and regions to form larger enterprises. However, as a result of ineffective outcomes, such a policy was only short lived (Naughton and Segal 2002; Ning 2007).[2]

The firms that drove the growth of the ICT industry in China were actually mostly medium-sized high-tech start-ups—many of which were spun off from Chinese national research institutes, universities, and government ministries—manufacturing computer products or providing computer services. The first such company was a technology consulting firm known as the Advanced Technology Service Department, established in 1984 by a researcher at the Chinese Academy of Science (CAS) in the Zhongguancun area of Beijing (Cao 2001). Another well-known PC manufacturing company was Great Wall, which was spun off in 1986 from the then Ministry of Electronics Industry (MEI). The government-sanctioned management buyout (MBO) policy resulted in the privatisation of many of these firms owned by the state or state-affiliated institutes—Legend (currently Lenovo) was the first. Originally controlled by CAS' Institute of Computing Technology, Legend was corporatised in 1998, with the management acquiring 30 per cent of the shares (Ernst and Naughton 2008). Other leading Chinese ICT firms—such as Datang, Founder, Huawei, and Semiconductor Manufacturing International Corporation (SMIC), for example—were in joint public–private ownerships. MBOs spread to cover township and village enterprises (TVEs) controlled by local governments, in the 1990s, and even small- and medium-sized state firms, in the 2000s (Ernst and Naughton 2008).

From 1986 to 1992, the Chinese government implemented a policy designed to promote four targeted industrial sectors—integrated circuits, computers, telecommunications equipment, and software—thus, further boosting the development of the ICT industry. In March 1986, to develop and commercialise indigenous high technologies, the government approved a strategic '863 Plan' (so called simply because of the timing of its kick off). The 'Torch Programme'—implemented in 1998—was an offshoot of the 863 Plan, devised to provide the institutional and infrastructural environment needed to foster the development of high-tech industries and the commercialisation of new technologies. In a first instance, 54 Science and Technology Industrial Parks

[2] China is divided into provinces, which are both geographical and administrative. Each province is committed to its own industries, and is reluctant to cooperate with other provinces. Central government found it very difficult to overcome provincial separatism in the interests of a 'big business' approach. Tackling provincialism at the same time as everything else was too much.

(STIPs) and High-Tech Industrial Development Zones were established in a number of regions in China—firms operating in these Parks / Zones benefited from preferential government treatment and incentives. The same year, a newly established Ministry of Information Industry (MII) replaced the old MEI—seen as no longer suitable for fostering further growth, due to the specialised nature of the ICT industry (Kraemer and Dedrick 2002). With a view to stimulate the further growth of domestic ICT firms, the government implemented a number of industrial policies. These policies included (1) the establishment of tariff and non-tariff (for example, quota) barriers to protect the domestic market; (2) the building of supply chains through government procurement and local content requirements; and (3) the provision of direct government subsidies for R&D technology transfer, financial incentives, tax reliefs, and preferential loans (Ning 2007). With China's accession to the World Trade Organization (WTO) in 2001, tariffs on many ICT products—such as semiconductors and semiconductor manufacturing equipment, computers and computer parts, software, telecommunications equipment, and computer-based analytical instruments, for example—were progressively reduced until completion in 2005. Under the WTO agreements, China was restricted in the use of trade, technology, and industrial policies to promote its own industries.

Towards the end of the 1990s, many US multinationals entered into joint ventures with leading Chinese PC manufacturers such as Legend and Great Wall, with a view to produce desktops, laptops, servers, and peripherals—and with the hope that market share in China could be increased (Saxenian 2001; Kraemer and Dedrick 2002). Offshore production by foreign multinational firms was one of the most popular forms of foreign direct investment (FDI) in the ICT industry, due to the cost advantage of manufacturing in China—the Taiwanese FDI in the Chinese ICT industry was among the largest. Taiwanese ICT manufacturers have increasingly invested offshore in China, since the 1990s—in low-value added PC peripherals such as mice, keyboards, and power supplies, initially, and in higher-value products, such as scanners and motherboards, subsequently. By the end of 2001, the Taiwanese government had lifted the restriction on offshore production of higher-value added products in China, leading to the relocation of the production lines of high-value added ICT products—such as notebook PCs and liquid-crystal display (LCD) monitors, for example—to China at an extraordinary pace. The Taiwanese production volume of notebook PCs and LCD monitors in China increased exponentially, from 6.7 per cent and 3 per cent in 2000 to 97.8 per cent and 91.5 per cent in 2007 respectively (III 2007; III 2008). By 2004, China had become the world's largest producer of computer hardware products, surpassing even the US and Japan (III 2003). This leadership position remained unchallenged at least until 2012—in 2011, for example, China contributed 50 per cent of the mobile telephones produced worldwide, 61 per cent of the computers, 48 per cent of the colour television sets, 80 per cent of the digital cameras, and 13 per cent of the integrated circuits (III 2011). As a result, many SMEs in China were drawn OEM into the global ICT value chain for a range of ICT hardware products.

There has also been an increase in the number of multinational firms offshoring product R&D to their China affiliates or outsourcing the function to specialised suppliers in China. With an abundant supply of low-cost R&D personnel, it is more cost effective for foreign multinationals to conduct product R&D closer to their manufacturing base in China. A survey of the world's largest R&D spenders showed that China had become the third most important offshore R&D location, by 2004, after only the US and the UK (UNCTAD 2005; Ernst 2008). The foreign multinationals intended to carry out product R&D in China in order to develop new products and processes that would suit the Asian market (Armbrecht 2003; Ernst 2006). In recent years, high-tech start-ups in Silicon Valley were required to present an 'offshore outsourcing' plan as a precondition for funding by venture capitalists (Ernst 2007). In the first nine months of 2006, a record USD 1.18 billion was invested by venture capital firms in 145 deals in China—ICT was the largest single industry that attracted a rising share of foreign funds (BMI 2009). For the non-equity form of R&D outsourcing, China was the world's third most important offshore location, in 2004, again behind only the US and the UK (Ernst 2006).

Since the year 2000, various firms in China have been engaged in the production of a diversified range of software products, including system software, maintenance software, and application software. Their marketing and sale were targeted initially at the domestic market, but expanded later to cover foreign markets. In 2000, Chinese firms produced USD 400 million worth of software for export—by 2005, this figure rose to a dramatic USD 3.6 billion (Ilett 2006). The same year, the Chinese government issued the *Policies for Encouraging the Development of Software Industry and Integrated Circuit (IC) Industry*—their major objectives were to simplify the approval of jointly or foreign-owned IC enterprises and grant the IC industrial sector various incentives and suitable intellectual property protection (Heng 2008; MOFCOM 2009). Since then, both Taiwanese and US companies have made major investments in semiconductor manufacturing in China, leading to a wave of USeducated Chinese who bring technological skills and knowledge back home. The recent move by the Chinese government to establish IC Incubation Centres was devised to consolidate resources in designing advanced and specific ICs, tailored for the needs of downstream semiconductor manufacturers. It resulted in notable investments by renowned IC companies and foundries in the US and Taiwan—such as Intel and Taiwan Semiconductor Manufacturing Company (TSMC), for example.

Since late 2007, the Chinese government has been implementing a policy promoting the integration of informatisation and industrialisation and the application of information technology to various industrial sectors. As a result of increasing domestic market demands, the production value of the software and system integration sectors grew by an impressive 44 per cent in 2010 compared with the previous year, pushing the output value up to USD 201 billion (III 2011). The Chinese government identified cloud computing as a new driving force that can be applied in various industries—particularly in government and medical services, telecommunications, education, finance, and electronics. The market for ecommerce-related services also grew significantly in China, because of an increasing degree of acceptance—by both corporate and retail customers—of online purchasing and business transactions. As a result of active government promotion, the software markets for ecommerce and cloud computing entered a period of fast expansion, growing by 72 per cent in 2011 compared with the previous year and reaching USD 4.5 billion. By contrast, the domestic market for ICT hardware and consumer electronics stabilised, due to decline in general public consumption demands coupled with Chinese overproduction of such products. However, due to aggressive marketing campaigns by three big telecommunications carriers, the popularity of the broadband services, and the construction of the long-term evolution (LTE) networks, there has recently been a significant growth in the domestic markets for smart phones and network hardware and related IC products. To satisfy growing domestic market demands, the Chinese government has also been promoting the digital content sector of the ICT industry, with high value-added and requirements to meet the Chinese culture (III 2011). Last but not least, the Chinese government's subsidy to promote the purchase of green ICT consumer goods in the second half of 2012 is expected to boost demand for such products and drive further the ICT hardware sector (III 2012).

## The upgrading trajectory and model of the ICT industry in China

Like in other developing countries, SMEs in China were connected to the global ICT value chain as suppliers of various ICT products. However, they were not the main actors charting the upgrading trajectory of the domestic ICT industry. Instead, SMEs—particularly those SMEs clustered in high-tech Parks and Zones—used production technologies provided by multinationals or contract manufacturers. While they might have gradually acquired new technologies from multinationals, SMEs lacked the resources needed for further upgrading their technological capacity—they were locked in the low-end production function, barred from advancing and engaging in more innovative and higher-value added activities along the global ICT value chain (Wang 2006). At most, SMEs were grasping industrial gains concentrated at the lower-end of the global ICT value chain.

Few SMEs in China became component suppliers for foreign firms or ODMs for Taiwanese firms, which would have been essential in fostering the development of backward linkages in the ICT industry. According to the 2007 MoEA *Survey on the Operations of the Taiwanese Enterprises Investing in China*, only 12.95 per cent of the 45 responding firms in the computing, electronics, and optical products manufacturing sector sourced machineries, raw materials, parts and components, and semi-finished products from non-Taiwanese enterprises in China—the majority (75.85 per cent) sourced them from either Taiwan or Taiwanese enterprises in China (MoEA 2007). In most cases, sourcing decisions relative to critical components were made not by Taiwanese ODMs, but by global lead firms concerned about the quality of components supplied by Chinese companies. With the increasing popularity of the build-to-order production model, Chinese SMEs found it even more difficult to become component suppliers—the inventory risks of the model were too high for them (Yang 2006). Similarly, foreign electronics firms with manufacturing facilities in China tended to source strategic components such as microchips and disc drives from foreign suppliers (Luthje 2004). Chinese SMEs lacked the requisite human and financial resources to venture beyond the production function and expand into marketing and selling and distribution activities along the global ICT value chain, making it equally difficult for them to forge forward linkages in the domestic ICT industry.

Similarly, SMEs in China were not much involved in the outsourced R&D activities of brand name vendors, aimed at adapting home-base-developed technologies for commercialisation on the Chinese market. For instance, the

2007 MoEA *Survey of the Operations of Taiwanese Enterprises Investing in China* found that only 5.56 per cent of the responding Taiwanese firms conducting R&D activities in China used Chinese firms in the production network as R&D partners. Most Taiwanese firms adopted home-base-exploiting R&D strategies, seeking to adapt technologies developed at home for commercialisation on the Chinese market. Not surprisingly, a much higher proportion of the responding Taiwanese firms—55.6 per cent and 27.7 per cent, respectively—used their customers and raw material suppliers as R&D partners (MoEA 2007). To protect core technological competences, Taiwanese firms transferred only old technologies—used for manufacturing mature products—to their R&D units in China. Many R&D units in China were—at best—responsible for system integration R&D activities and—at worst—engaged only in the implementation of sub-modules or the preliminary testing of the encrypted system kernel (Lu and Liu 2004). For Taiwanese firms adopting home-base-augmenting R&D strategies to tap into China's knowledge base, the popular R&D partners were technology transfer units (for 50 per cent of respondents), higher educational institutes (for 38.89 per cent of respondents), and technology consulting companies (for 22.22 per cent of respondents) in China—certainly not the Chinese SMEs in their own production networks (MoEA 2007).

The upgrading of the ICT industry in China was fostered more by domestic high-tech start-ups and large privately owned firms than by SMEs. Many of the Chinese domestic high-tech start-ups had close connections with national research institutes, universities, and government ministries. Spin-offs from public and related organisations, domestic high-tech start-ups were able to obtain core technologies from the associations with which they had previously connected. They also had a high degree of autonomy in formulating and implementing firm strategies to compete in the highly volatile and uncertain industrial market. Depending on the choice of corporate strategy, these companies might have initially engaged in product distribution, then entered into joint ventures with local or foreign firms, acquired foreign or local companies to form more complete product lines, or licensed the right to use proprietary technologies possessed by foreign companies. Medium-sized high-tech start-ups and large private firms—not the SMEs, lacking in both human and financial resources—forged forward and backward linkages along the domestic ICT value chain. Moreover, though medium in size, the high-tech start-ups benefited from connections with national research institutes, universities, and government ministries—and therefore from better access to existing technologies—unavailable to the SMEs. Engaging in the distribution function embedded in the global ICT value chain allowed these Chinese firms to better understand the market trends—in turn, this enabled them to move upwards and engage in higher-value added activities. Also, buying in new technologies and assimilating technological knowledge from various organisations operating along the global ICT value chain allowed them to generate more innovative products and services.

Most of the private ICT firms in China were engaged in developing architecturally or incrementally innovative products. Architectural innovations require strong system integration and strategic marketing capabilities, but are not demanding in terms of scientific inputs and investment commitments (Ernst 2008). They seek to develop new products by changing the product architecture without the need to use highly technologically advanced product components. ME60 is one good example of an architecturally innovative product. ME60 is an edge router that sits between the Internet Protocol (IP) core and the access network, enabling telecommunications operators to aggregate multiple services from various networks into one IP core—thus, improving real time control over the services (Ernst 2007). Developed by Huawei, China's largest telecommunications and networking equipment manufacturer, ME60 was the first integrated IP service platform on the market. The Tianxi laptop manufactured by Lenovo is another good example of an architecturally innovative product, aiming to provide—through prior arrangement with China Telecom—easy Internet access at an affordable price, tailored for the needs of private consumers and small businesses in China (Ernst 2008). Like Lenovo, many other Chinese private ICT firms started off as distributors of foreign products, enabling them to acquire marketing and selling skills. Using existing component technologies supplied by specialised firms, they developed architecturally innovative products and services. Familiarity with the characteristics of Chinese consumer preferences, markets, and institutions allowed these local ICT firms to suggest products—with essential performance features—much less expensive than those offered by global industry leaders. In fact, the global lead firms' relative lack of understanding of local consumer requirements—as well as of domestic market and local institutional characteristics—rendered them oblivious to the presence of a market for architecturally innovative products, which could help resolve practical technological problems and bring convenience to end consumers.

Similarly to architectural innovations, incremental innovations require no substantial investments and inputs from science. Instead, they require entrepreneurial and managerial capabilities, as well as capabilities to provide integrated solutions based on familiar tools and methodologies. Operating in a highly price-sensitive domestic market, the Chinese ICT firms were forced to pay particular attention to cost, time-to-market, and performance issues. Consequently, they were able to exploit all manner of opportunities to suggest incremental innovations along various segments in the value chain—including R&D; production; and the management of supply chains, customer relations, and information systems (Ernst 2007; Ernst 2008). Apple Peel 520 is one recent example of an incrementally innovative product, originally invented by two Chinese brothers and subsequently mass produced by Chinese ICT firms. Apple Peel 520 is a case containing a circuit board and battery that could be wrapped around an iPod Touch media player to enhance its function so that calls could be made after software has been installed (Culpan and Conley 2010). By using Apple Peel 520 (priced at around USD 74), an iPod Touch (priced at around USD 233) could be converted into an iPhone, and consumers would need to pay only a fraction (around USD 307) of the price of an iPhone (priced at around USD 1,190) to own a non-iPhone device with full iPhone functionality (Jones 2010).[3] The average Chinese consumer was unable to afford an iPhone, but was prepared to purchase a similar—albeit less sophisticated—product for a lower price. The business potential inherent in this market remained culturally obscure to global ICT industry leaders, but not to Chinese entrepreneurs in local ICT firms.

Building on capabilities in making architectural and incremental innovations, many private ICT companies in China adopted a technology diversification strategy, using applied research to broaden their technology base. Component and process technologies that were neither new nor difficult to acquire were used to develop new products (Ernst 2008). Chinese private ICT firms obtained these technologies through leveraging different types of networks formed with market and technology leaders, such as licensing arrangements and non-equity partnership arrangements. By adopting a technology diversification strategy, Chinese ICT firms were able to generate technology-related economies of scope to strengthen their capabilities in process development, prototyping, and electronic design, providing consumers with 'integrated solutions' (Ernst 2007).

Isolated innovations occurring at firm level were substantiated by the industry policies implemented by the Chinese government. They included the provision of preferential tax incentives, to help SMEs develop into high-tech enterprises, and the setting up of new capital markets (such as the SME Board on the

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[3] The prices are valid as of July–September 2010.

Shenzhen Stock Exchange, for example), to help SMEs raise the capital required for developing new technologies. There were also support policies, to promote the operation of innovation service agencies such as the Technology Business Incubators and National University Science Parks. Funding was provided to establish public service platforms and foster the implementation of business cooperation projects in industrial clusters (Torch High Technology Industry Development Center 2013). In 2006, a clear policy direction was laid down in *The 11th Five Year Plan for the Technology Development of the Information Industry* to upgrade the indigenous innovation capabilities of the major actors in the ICT industry, the main objective of which was to enable them to control critical technologies (CNII 2006). By encouraging the development of strong support industries and linkages between private ICT firms, on the one hand, and universities and research institutes, on the other, the structure of the ICT industry was very much strengthened.

## Conclusions and theoretical implications

It is beyond dispute that the ICT industry in China enjoyed a phenomenal growth rate over the past 25 years. After their humble beginnings in the early 1980s, the Chinese ICT firms became the world's largest producer of computer hardware products in 2004, surpassing even their counterparts in advanced industrialised countries like the US and Japan. This leadership position remained unchallenged at least until 2012 (III 2011). Besides manufacturing hardware products, an increasing number of Chinese ICT firms engaged in developing various software as well as producing semiconductors and other IC components. Could we then conclude that the Chinese ICT industry has followed the trajectories of counterparts in other developing countries to leverage participation of SMEs as producers in the global ICT value chain, gradually upgrading along the chain? The answer to this question is negative. Although they played a part in fostering the upgrading of the Chinese ICT industry, SMEs were not the major actors charting the industry's upgrading trajectory. Chinese SMEs were engaged in production and, in some cases, product development of ICT commodities outsourced or offshored by foreign brand name vendors—however, they were barred from involvement in the production and product development activities of higher-value added, innovative products. Foreign brand name vendors carefully protected their core technological competences, transferring only old technologies for mature products to Chinese SMEs. Since SMEs lacked both the financial and human resources necessary to upgrade their technological and managerial capabilities, they did not play a major role in forging backward and forward linkages in the domestic ICT industry to become component suppliers, marketers, or distributors of ICT products.

The upgrading model of the ICT industry in China is unique to a large country which developed late. The upgrading experience of the Chinese ICT industry is different from that of smaller economies—like Taiwan—which developed earlier. To reach the innovation frontiers set by global lead firms, small Taiwanese manufacturers of ICT products and providers of ICT services had adopted a fast-follower strategy—the technology gap between global lead firms and small Taiwanese firms was closed incrementally, with each new generation of products and services. However, such a strategy was not very useful in the institutional and technological contexts within which Chinese ICT firms operated. The institutional barriers emerged as a result of the global lead firms stepping up actions to protect their proprietary technologies—a hard lesson learned from past experiences in outsourcing and offshoring production activities to developing countries. The technological barriers emerged as a result of the digital convergence trend, rending the fast-follower strategy largely irrelevant in the current technological context. Nowadays, data, voice, and video can all be turned into digitalised signals to be transmitted via telephone lines or the Internet and received by a wide range of products including personal computers, Internet television sets, game consoles, smart phones, and personal digital assistants (PDAs). Various innovative computing, consumer electronics, communication, and content products (4G, for example) are now competing to be chosen by consumers as data receivers, voice transmitters, and video players to perform a number of integrated functions (III 2007). Current competition is based on the ability to accurately anticipate future market trends and the capability to create new concepts, develop novel component technologies, and establish as well as control emerging industry standards for the innovative products which are to be chosen by consumers to perform integrated functions.

Large Chinese private ICT companies played a much bigger role than SMEs in fostering the upgrading of the ICT industry. They acquired component and process technologies—by leveraging various types of networks formed with market and technology leaders—and pursued a technology diversification strategy to broaden their technology base and develop a range of architecturally and incrementally innovative products. Knowledge of the characteristics of the domestic market allowed Chinese private ICT firms to apply existing component technologies on new product architectures, developing architecturally innovative products that were not over-engineered and that could provide low-cost integrated solutions to customers' needs. An early example of such products is the electronic switching system HJD04, developed to optimise performance features in line with the specific characteristics of the Chinese telecommunications network structure and the specific needs of the service providers (Shen 1999). More recent examples include ME60, the first integrated IP service platform, produced by Huawei, and Tianxi, the laptop manufactured by Lenovo (see pp. 65). Chinese private ICT firms possessed capabilities in managing cost, time-to-market, and performance, and provided OEM for global brand name vendors, using familiar tools and methodologies to generate incrementally innovative products and services. Isolated firm-level innovations were substantiated by the industry policies implemented by government to foster the development of support industries and the establishment of industry linkages between firms, on the one hand, and local universities and research institutes, on the other. With the structure of the Chinese ICT industry thus strengthened, further innovations took place at firm level.

The role of the Chinese state in strengthening the industry structure and facilitating the development of an environment conducive to technological innovation should not be understated. The Chinese government has played a significant role in creating a framework for the implementation of industrial policies and programmes promoting the development of the ICT industry. For example, in 1986, the Chinese government set up the so-called IT Fund—the Development Fund for the Electronics and Information Industry—to support indigenous research and development of core ICT technologies and products (China Electronic News 2011). For another example, the Torch High Technology Industry Development Center (herewith, the Torch Center) was founded in 1989 under the auspices of the Ministry of Science and Technology (MOST) to implement policy tools that foster the development of high-tech industries and the commercialisation of new technologies through the promotion of innovation. Recently, the Torch Center has been restructured to take up an expanded function and lead in the building of an environment for innovation and in fostering high-tech industrialisation in China (Torch High Technology Industry Development Center 2013). More recently, in 1999, the Chinese government set up Innofund to support innovative technology projects with good potential markets and products commercialised at an early stage by technology-based SMEs not otherwise attractive to private capital (Torch High Technology Industry Development Center 2013). The Chinese government has also implemented policies providing software and IC enterprises with corporate income tax holidays—beginning from the first profit-making year before the end of 2017—and immediate refunds of the value-added tax (Cai, Wong, and Leung 2011).

The case of the Chinese ICT industry illustrates the usefulness of the GVC perspective in explaining the trajectory of the industry upgrading of large and late developing countries. However, initially, the GVC perspective was developed in a context very different from that currently faced by firms in large and late developing countries. Proponents of the GVC perspective need to take into consideration the changing nature of the institutional and technological contexts as well as their impact on the industrial upgrading of developing economies—the fast-follower catch-up strategy to close incrementally the technological gap behind the innovative frontier set by global lead firms in advanced industrialised countries is rendered useless by the presence of both technological and institutional barriers. With huge and booming domestic markets characterised by consumers seeking products and services at levels of sophistication less obvious to the lead firms in advanced industrialised countries, firms in large and late developing countries need to pursue a model of industrial upgrading different from that adopted by firms in relatively small and early developing countries. However, to develop architecturally and incrementally innovative products and services not culturally obvious to foreign competition, firms in large and late developing countries have to make good use of their knowledge of local consumer preferences and needs—as well as of the characteristics of domestic markets and institutions.

The case of the Chinese ICT industry also points to the need for proponents of the GVC perspective to re-examine the definition of industrial upgrading as the acquisition of technological capabilities and market linkages that enable firms to improve their competitiveness and move into higher-value activities. There are process, product, functional, and inter-sectoral forms of upgrading, all of which are conceptualised to take place at the level of the firm. However, as the case of the Chinese ICT industry has illustrated, firm-level innovations are by no means indicative of successful upgrading at industry level. Isolated innovations at firm level cannot be sustained, if industrial and related policies are not formulated and implemented by government—at both national and local levels—to mobilise human, technological, and capital resources; develop an innovative support system; as well as foster the growth of technology-based SMEs and innovation clusters. It is important that the concept of industrial upgrading be reappraised and the definition reconsidered.

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**Teresa Shuk−Ching Poon** is Associate Professor at the Lee Shau Kee School of Business and Administration at the Open University of Hong Kong (OUHK), having previously taught in both Hong Kong and Australia.

Teresa has received her undergraduate and postgraduate education in Hong Kong, the UK, and Australia. She was awarded her PhD in work and organisational studies by the University of Sydney, Australia, in 1999. The same year, Teresa was invited by the International Labour Office (ILO) to address the International Conference on Responding to the Challenges of Globalization: Local and Regional Initiatives to Promote Quality Employment through Social Cohesion held in Bologna, Italy. Later on, in 2005, ILO and the Japan Institute for Labour Policy and Training (JILPT) invited Teresa as a subject expert to the Fifth Round of Joint Investigative Studies on Promoting Decent Work in Global Production Systems in Asia and the Pacific held in Bangkok, Thailand. Between 2002 and 2005, she was appointed by the Special Adviser to the United Nations Secretary General on the Task Force on

Science, Technology and Innovation–this working group had been established under the UN Millennium Project to give expert advice on the best strategies for meeting the Millennium Development Goals.

Teresa has been involved in several international comparative research projects examining the impact of globalisation on employment relations in the retail and corporate banking sectors as well as the low-cost airlines industry in different countries. Her current research focuses on global value chains, industry upgrading, skill formation, and innovation, particularly in Asian economies such as China and Taiwan. In addition, she explores the idea of marrying the global value chains perspective with research on employment relations and human resource manage ment studies.

Teresa can be contacted at tpoon@ouhk.edu.hk, at the Lee Shau Kee School of Business and Administration at the Open University of Hong Kong.