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East Asian Growth:
Chinese R&D Sourcing and Patenting Behaviour in ICT

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Preface

R&D activity in the Information and Communication Technologies (ICT) industrial sectors is an important factor in boosting the competitiveness of the European economy. The ICT industry and ICT-enabled innovation in non-ICT industries and services is making an increasingly important contribution to economic growth in advanced economies. The ICT sector was highlighted in the EU Lisbon Objectives, and has retained its prominence in the recently proposed **Europe 2020 Strategy**.

The Information Society Unit at IPTS[1] is carrying out a research project on Prospective Insights on R&D in ICT (PREDICT)[2] and has produced a series of annual reports. PREDICT combines, in a unique way, three complementary perspectives: national statistics (covering both private and public R&D expenditures), company data, and technology-based indicators. PREDICT relies on the latest available official statistics delivered by Member States, Eurostat and the OECD.

The first part of each annual PREDICT report gathers the most recent quantitative information on ICT R&D investments in the EU and worldwide. It presents the data by countries, sub-sectors and companies. The second part of each report is dedicated to a specific thematic analysis. In 2010, it focused on the internationalisation of ICT R&D.

This thematic analysis is based, in part, on an earlier study which focused on the ICT sector and R&D in East Asian countries in order to gain a better understanding of major ICT capabilities in those parts of the world.[3] The present report provides a synthesis of one of those studies.

This overall research exercise on internationalisation led to a series of further reports. All of them are available on the IS Units website of the IPTS.[4]

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1 IPTS (the Institute for Prospective Technological Studies) is one of the 7 research institutes of the European Commission's Joint Research Centre.

2 PREDICT is co-financed by JRC-IPTS and the Information Society & Media Directorate General of the European Commission.

3 This report was commissioned during the period 2005-2007 by JRC-IPTS as part of the study "Towards Knowledge-based Societies. ICT for Growth and Cohesion in a Global Knowledge-based Economy: Lessons from East Asian Growth Areas". The research consortium included Frans van der Zee (TNO), Simone Kimperle and Thomas Stahlecker (Fraunhofer ISI) and several non-European PhD grantholders. It was coordinated by Professor G.N. Von Tunzelmann from SPRU, University of Sussex, UK to whom JRC-IPTS is very grateful.

4 Available on our website under the link http://is.jrc.es/pages/ISG/PREDICT.html

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1. Introduction

This study argues that Chinese firms are rapidly developing competitiveness at the high end of the ICT industry in general and of telecommunications in particular. Based on patent data and on case studies of Chinese corporate strategies and behaviour, it also analyses the technology transfer and R&D activities connected to that process. The development analysed here may be a challenge for those firms which dominate the world market at present. In addition, it challenges the orthodox view of globalization and of the catching-up of Newly Industrializing Economies (NIEs) in global business. The new competition – it is argued – goes far beyond the labour-intensive segments of ICT and threatens the core of traditional competitive advantages for 'old' industrialized country-based firms in their systems competence and knowledge-intensive activities. Furthermore, it challenges the dominant view on the incumbent international firms which are supposed to maintain or even strengthen their positions in world markets through their global sourcing of knowledge production. Finally it contributes inputs to the emerging discourse on the globalization of knowledge formation. This process increasingly includes countries – and firms from countries – which until recently had always been perceived as lagging behind the technological frontier

ICT, which is an enabling technology for this new round of Asian tiger growth, is actually not the focus of this study. Rather, by drawing from field studies of the China-based and China-related ICT industry itself, the study focuses on the learning mechanisms and catching-up strategies deployed so far, at the firm level and at the industry level. Although this study primarily addresses what may be labelled 'the meso level', and is restricted to China, it is intended to contribute to the general understanding of recent waves of Asian growth.

This report was written as a contribution to a wider study on Asian Growth.[5] It does not aim to offer full coverage of the subject but rather to place some of the pieces in the puzzle to gain some understanding of the present dynamics of global transformation.

The study is structured as follows: in Section 2, we provide a short introduction to the catching-up phenomenon led by the Chinese ICT industry and discuss some problems in understanding the transformation processes taking place. In Section 3, based on field studies of the Chinese ICT industry and their overseas R&D labs, Chinese ICT patenting in the

[5] "Towards Knowledge-based Societies. ICT for Growth and Cohesion in a Global Knowledge-based Economy: Lessons from East Asian Growth Areas".

USPTO and Chinese patent behaviour (at least in the ICT industry) in general, we analyse the trends in the new globalization context. We also question whether the IPR thicket is as formidable as argued and whether the latecomers are pursuing a different path to the one usually followed in ICT patenting. This section is based on two recent papers from our research project at the Royal Institute of Technology, Stockholm. Section 4 contains a short concluding discussion.

2. Setting the scene

Before moving into the details of Chinese development within ICT we should remind ourselves that catching-up processes have taken place on a global level as long as there have been countries/regions which from one reason or another tend to run away faster than the others. Starting with Veblen this catching-up process has also been analysed by academia (for an overview, cf. Fagerberg & Godinho, 2003).

As regards *la longue durée* we should remind ourselves that China, following a period of (probably) rapid technological development around 1400 A.D., had a clear technological advantage over Europe in most technologies of importance. Although there were technological development processes taking place in the following centuries it is clear – and still an unsolved problem for historians – that there was a steady European catching-up (i.e. a relative Chinese stagnation) in the centuries to come; often labelled 'the industrial revolution' (Mokyr 2000).

The top seven performers as regards recent catching-up (since 1960) are all from Asia, with GDP growth rates ranging from 6.5% (South Korea) to Japan (approx. 4 %). China is a late starter but has still reached an average growth rate exceeding 4% during the last four decades and has during the last two decades had twice that growth rate.

For a long time, research into catching-up processes has been analysing the easiness or difficulties of the technology transfer needed and the institutional and cultural transformations necessary. Gerschenkron (1962), for example, argued that these processes are so demanding that they necessitate strong market interventions, e.g. by policy institutions. He also argued that the latecomers should focus on rapidly growing, technologically advanced industries. That raises the problem of to what extent the latecomers may successfully leapfrog directly to the 'high end' of the world market. The mirror image of this is the problem of what kind of competencies and capabilities among the early entrants are most or less resistant to acquire and/or to be learnt by others (the latecomers).

Global sourcing of simple manufacturing and assembly processes, even in high-tech industries like ICT, is not a sufficient condition for the creation of such a development – that is shown by the case of Ireland. Obviously the dynamic potential by various forms of sourcing and technology transfer (learning) will depend on local conditions. Some of these at least may be possible to influence through policy.

In their classic and thorough study on technology transfer Enos & Park (1988) analysed the Korean acquisition of technology which – it may be argued, although not by them – was well in line with the Gerschenkronian position, i.e. focusing on the most advanced technologies available and being strongly supported by government policies giving high priority to economies of scale and high productivity and output. In general, their study showed impressive absorption capacity followed by rapid learning by doing and using advances.

As regards China the technology transfer problem was investigated by a team from the British Academy visiting Beijing in 1995 (cf. Feinstein & Howe, 1997). One of the classical problems – the incentives for innovation and technology transfer in socialist systems and under monopoly capitalism compared to competitive capitalism – was dealt with in detail and related to Chinese conditions. As is shown in several of the contributions to the anthology, the open-door policy adopted around 1979/80 may be looked upon as a watershed as regards technology transfer; to a high extent realized through FDI and JVs between Chinese and overseas firms. Fully in line with his earlier research results Enos, in his contribution to the Feinstein-Howe anthology (ch. 6) argues that the capacity to improve the performance of acquired technologies – i.e. the learning and innovation processes taking place after the transfer has been completed – by far outweighs the importance of the transferred technologies *per se*.

The political reorientation measures taking place in China from around 1979/80 were strongly connected to the Deng Xiaoping government coming into power in 1978. Among other things, that government introduced four modernization programmes in Agriculture, Industry, Science and Technology and Defence (Fairbank 1992: ch. 21). As a result of that new policy orientation China gave high priority to a leapfrog strategy rather than the smoother upgrading path which has been labelled 'the flying geese strategy' (cf. Wall & Xiangshuo in Feinstein & Howe).

Although many of today's successful countries developed rapidly – but not leapfrogging in the strong sense – into fast-growing sectors it has been argued that the "radical technological change in the last decades, with ICT-based solutions substituting earlier mechanical and electromechanical ones, and the derived change in the demand for skills and infrastructure" has made it more difficult for latecomers to catch up, leaving that road open only for those countries which have invested massively in the formation of skills and R&D infrastructure (Fagerberg & Verspagen 2002).

Superficially, this is not the case with China. Although fast growing, as shown in many recent reports, the country ranks low as regards enrolment in higher education, university degrees in natural sciences and engineering or R&D intensity and patenting activities. These figures may all be the result of a statistical illusion due to an aggregation over an enormous country which is divided between an advanced economy (basically coastal) and an immense backward 'hinterland' related to, but still not fully integrated in, the modernization process. As several analysts have argued, China from many aspects is too large a country to look upon as one unity (cf. Fairbanks 1987).

A detailed analysis of this statistical illusion falls outside the scope of this study. In the following we abstain from working with per-capita information in order not to average out the size and dynamics of Chinese transformation. It is enough here to illustrate the phenomenon:

Similar to many historical development processes, the Chinese transformation is characterised by a severe inequality. Probably 200-400 million people are included in a rapid growth process, leaving approximately 1,000 million far behind. Regardless of whether they face real improvements or not (the details of which we have not studied) it is obvious that average data hide many aspects of the dynamics of the process.

3. The details of our analysis

In the following, we summarize the results of our in-depth study of R&D sourcing and technology transfer in the Chinese ICT industry.

In addition to patent data and some Chinese R&D statistics our study is based on more than four sets of field trips during 2003-2006 with around 70 interviews (see Appendix 1), covering Pearl River Delta, Yangtze River Delta and Bohai Rim region, as well as inland regions like Xian and Chengdu in China, and including interviews with 55 ICT firms (six Western firms included), six national and local government authorities' offices, four high-tech parks and one economic development zone, and three universities. We also have had interviews with industry employees in Sweden and in Finland. Our study of R&D activities within the ICT sector is primarily interview-based. It draws on case studies of Chinese corporate strategies and behaviour, analysing the technology sourcing and R&D activities connected to that process. We have thus not performed any quantitative study of the distribution between domestic actors, foreign actors and joint ventures. Neither have we analysed the distribution between different sub-sectors within industry (e.g. telecom operator and equipment vendors).

Reference details in the section below can be found in Long & Laestadius (2006) and Long & Palmberg (2006).

3.1 Global R&D Sourcing

Our project supports the conjecture of a new and third mode of globalization.

The *first stage of globalization* – it may be argued – was based on trading and has been going on for centuries, more or less supported by colonial and imperialist endeavours from dominating states (cf. Braudel 1979; 1986).

The *second stage of globalization* may be located to the 1970s or even earlier when the first real global production networks (GPNs) emerged (Laestadius 1980; Ernst 2002; Hobday 1995). During the 70s there was an intense discussion of the mechanisms behind and consequences of the new international division of labour connected to increased production and export of manufactured products from third-world countries. Knowledge diffusion (e.g. technology transfer) in this second stage of globalization was still basically one-way. The R&D labs of the big multinationals were basically located in the old industrialized world and

so were the qualified and advanced customers. The conventional wisdom, therefore, argues that, although an advanced relocation of production facilities has taken place on a global scale, multinationals are still surprisingly non-globalized as regards knowledge formation, namely keeping the highly profitable knowledge-intensive segments of the value chain in the old industrialized economies (cf. Pavitt & Patel 1991). The innovation process is thus assumed to have strong tendencies towards spatial clustering in the advanced economies (Kenney & Florida 2004). On the whole these conclusions have been repeated in recent research, arguing that high-tech firms located in Asia tend to specialize in low profit activities behind the frontier. The strong consolidation of international firms – the big-business revolution especially pronounced in the automobile industry – is also often assumed to block the ambitions by Asian (not least Chinese) firms to develop competitiveness in international markets (Nolan 2001; Nolan & Zhang 2003).

The new mode of globalized knowledge formation processes – *the third phase of globalization* – may be illustrated by recent statistics on science citations. Chinese scientific publications and citations in international journals have seen a dramatic increase recently. In 1995, China produced 10,800 internationally cited papers in English. Ten years later (2004) 51,200 papers were recorded by SCI; an increase of almost 17% per year (ISI database). Last year (2005) 61,600 papers were published – an increase of another 20%! That was also the year when China passed the UK as regards citations in scientific journals. The rising productivity of Chinese scientists seems in line with the process in other SE Asian countries like South Korea and Singapore (Leydesdorff forthcoming; Choung et al. 2003). Our patent database study of Chinese patents in the USPTO reveals a similar pattern of China to South Korea in the innovative technology areas, namely the technological sub-sectors in mechanical engineering and electronics take the lead in the catching-up process (Long & Palmberg 2006). In certain areas, for example in nanotechnology, China has recently surpassed the USA in terms of numbers of publications (King 2004).

Fully in line with some other recent studies our analysis reported below – to a large extent based on interviews – shows that Western incumbent ICT firms are starting to move more advanced R&D activities to developing regions, and a group of fast-growing high-tech firms from the emerging economies are aggressively building up R&D labs in the advanced economies (see our empirical findings). Together with the size and rapid growth of advanced Chinese ICT markets this flow creates a global convergence of knowledge formation. Local

conditions in Chinese sub-regions (e.g. the 'three locomotives' along the coast), network externalities, and the mobility nature of ICT technologies, may contribute to this process.

Six characteristics of this stage of globalization may be identified, although some of them may be more relevant for a giant like China than for smaller economies:

i) The depreciation and obsolescence rate of knowledge has never been so fast while the exchange of both information and knowledge has never been so intensive.

ii) Knowledge now flows in both directions. The old one-way connotation of 'technology transfer' is rapidly becoming obsolete. Globalization of learning in this new context is an active, multi-direction process requiring high interactivity at individual, organizational and cross-disciplinary level.

iii) The globalized knowledge flow is both highly random (i.e. user-centric innovations like Linux and the international availability of scientific results) and organized behaviour by MNEs and research institutes. At the organizational level knowledge formation becomes more pluralistic, contrary to the conventional wisdom as regards global business consolidation.

iv) Networking and alliances have been widely adopted as a risk-sharing model, like the fabless-foundry partnership in the semiconductor industry (Leachman & Leachman 2004). There is much less concentration of R&D in one single firm but more alliances appear (Palmberg & Martikainen 2005) and often they are non-equity based. In other words, knowledge formation is much more based on external links, both upstream and downstream, and at vertical and horizontal levels.

v) Globalization of knowledge formation has a strong political dimension. Today Singapore's position as an essential electronics hub is also thanks to government intervention; China's support in establishing a joint technology park in Austria aiming to encourage Chinese firms 'go-out' and help build a platform for Chinese high-tech companies to enter Europe may also illustrate this. When enabling technologies are in place, and a set of upstream suppliers, downstream corporations and final customers are integrated in certain government-created 'high-tech parks/zones', a new industrial district or valley is gradually cultivated through a federal knowledge formation effort backed strongly by the governments. This calls for a dynamic view on a global shift of centres of excellence.

vi) The global knowledge formation is an active process, resulting also from actors located in developing regions as seen in the emerging Chinese overseas R&D labs, participating in development consortia, acquiring Western patents and engineering expertise, and meanwhile searching for proximity to customers in the advanced markets by immersion in them.[6]

This is a challenge also to orthodox views on how international firms localize knowledge-intensive activities within a globalized economy. The new competition – we argue – goes far beyond the traditional labour-intensive segments of ICT and threatens the core of traditional competitive advantages for 'old' industrialized country-based firms in their systems competence and knowledge-intensive activities. This also challenges the dominant view on the incumbent international (IE-based) firms which are supposed to maintain or even strengthen their positions in the world market through their global sourcing of knowledge production.

The present globalization processes challenge the conventional wisdom as regards the competitive advantages of the industry/firms due to institutional and cultural factors and associated externalities of a national innovation system (Edquist 1997; Lundvall 1992; Porter, 1990). For firms involved in a global life-cycle and/or a technological regime and competing in various markets simultaneously, there are incentives to allocate innovation resources according to globally dispersed demand as well as factor conditions. Following a well-documented view of how international firms locate their R&D activities (e.g. Dunning 2000; Criscuolo et al. 2001) we can identify two main R&D-location strategies, which may be more or less complementary depending on the overall situation of the firm:

- 'Asset-exploiting R&D' or 'home-based exploiting (HBE)' mainly serve for "adapting and modifying the existing technological assets in response to demand conditions";
- 'Home-based augmenting (HBA)' research activities mainly conducted to "augment existing assets through absorbing and acquiring technology spillovers from local knowledge bases (public infrastructure or to benefit from agglomerative effects in a specific sector), or from specific firms."

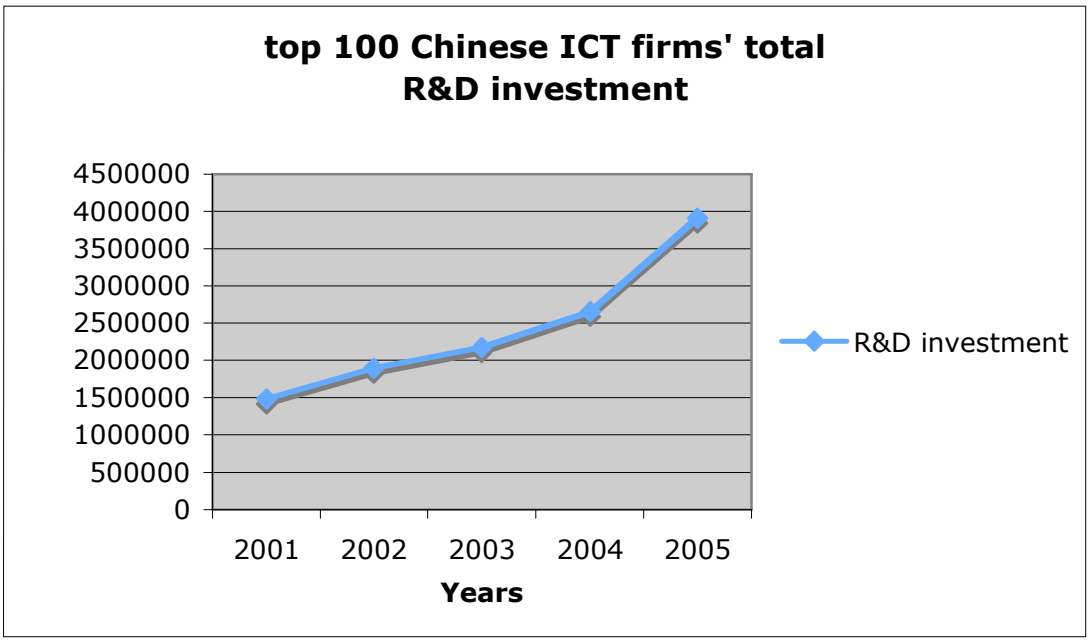
[6] ShenYang machine tool group recently acquired Schiess in Germany, a 140-year-old maker of heavy-duty lathes and boring machines on the one hand, the better to serve local customers. On the other hand, this firm will be able to draw on Schiess's expertise to produce large equipment for the Asian market – and to do it from China. "It takes years to acquire the complicated technologies" (*Business Week* 21 Feb. 2005: The Chinese are coming…to Germany).

Part of the motives further identified and studied here are also associated with the fact that the set of MNEs is increasingly consisting of actors from developing regions:

- Cost differences and labour sourcing.
- Learning implications – searching for proximity to centres of excellence.
- Agglomeration effects (i.e. externalities) are widely recognised as vital for locating R&D activities, namely the location of other firms (both upstream and downstream) and affiliated university scientists.
- Alliances and policies.

Although the access to Chinese corporate R&D statistics is in general limited, we have luckily located five years of R&D data (and ratios to sales revenue) of some leading ICT actors (top 100) in China, from industry statistics put together by the Ministry of Information Industry of China (cf. Figure 1). The majority of the actors who set up overseas R&D labs fall into this category.

Figure 1: R&D Investments (values) in Chinese Top 100 ICT Firms, 2001-2005



However, the transformation of Chinese ICT sector is so fast that annually published statistical information – due to publication lags – is of minor relevance as regards the actual state of events, although the yearly data change may indicate the magnitude of the transformation process. In addition we also found that the growth rate of leading firms was so

fast that even those who invested heavily in R&D faced declining or only modestly increasing R&D intensities!

Therefore we also conducted interviews with emerging innovative actors whose sales revenues do not fall in that category (yet) but developing inventions, based on our study of the secondary data (e.g. Chinese newspapers, high-tech park journals).

Our field studies in China indicate that catching up in the Chinese ICT (mainly telecom equipment) sector is much more knowledge-related than was ever foreseen by Paul Krugman in his famous paper on "The Myth of Asia's Miracle" (1994). Following the speeding-up of R&D internationalization taking place by countries outside the developed world (Chen 2004), we have in our empirical study identified two directions of international R&D flows:

- On the one hand, many Western ICT firms move not only HBE/asset-exploiting R&D activities but also HBA/advanced R&D activities to developing regions like India and China, often in cooperation with local firms (in this study, we focus on China).
- On the other hand Chinese firms, after 'initial knowledge and capital accumulation' through successfully encroaching on market shares from foreign vendors at home, and/or using the home market as an important 'cash cow', aggressively build up R&D labs in the advanced economies like the USA and Sweden.

Our observations and discussions with interviewees in the ICT industry on the historical path of those foreign labs seem to be in line with a general recent report from the Henry L. Stimson Center (Walsh 2003). Three stages of high-tech multinationals' R&D investment in China have been identified:

- *Exploratory and strategic partnership stage* in the early to mid 1990s, in which many R&D programmes were JV-based as a means to access the huge emerging market;
- *Expansion of the R&D investment stage* in the mid to late 1990s, in which R&D activities moved towards more intensive cooperation with leading Chinese indigenous firms and universities, meanwhile exploring the resources of Chinese western regions;
- *Consolidation of the R&D stage* after the late 1990s, in which China's accession to WTO and domestic development of high-tech technologies and size of the market drove the foreign R&D investment into a more consolidated, strategic approach with increasing FDI research labs (ibid.: 86-90).

Another recent study on the high-tech industries in China (Chen & Shin 2005) also seems to confirm this trend.

Our insights drawn from in-depth interviews, however, contribute to an industry perspective in particular rather than high-tech in general. Furthermore, they give insights on the internal dynamics of this industry (e.g. actors) and across regions.

We identify the fact that foreign R&D actors in China are not only from Triad regions (i.e. Western Europe, North America and Japan), but also increasingly from some newly industrialized regions. Furthermore, the actors across sub-ICT sectors seem to expand too. From a regional perspective, we identify that the majority of foreign labs are still concentrated in Beijing and Shanghai and other coastal regions. However, we see a gradual diversification to inland regions like Xian, Chengdu and Wuhan with high-class universities although not located in the hitherto 'hottest' regions.

A sophisticated market is a strong attraction for the location of R&D activities. USA and Europe have traditionally been areas with sophisticated customer demands triggering ICT development. There are also studies indicating that a position somewhat behind the technology frontier is the explanation – showing the strong forces of path dependence – of the fact that the first-tier Asian tigers had problems to develop and profit from the most advanced I&C technologies (Kenney & Florida 2004). Is this valid also for a second-tier tiger like China today?

A common view in the western world is that Chinese customers are not sophisticated enough to stimulate innovation in the high end of the market. These general views are based on studies of, for example, Average Revenue Per User (ARPU) of China Mobile Services. Although local operators like China Mobile have nearly 400 million subscribers today, their average profit margins from each user pale in comparison with those of operators like Vodaphone. Too much focus on westernized indicators like ARPU and earnings in international currency may, however, lead to invalid conclusions. Five features of the Chinese ICT market's sophistication and character may be distinguished in our field studies and observations, which we argue challenge the most superficial conclusions:

i) The *heterogeneity* of a big country like China (e.g. west-east gaps, high-income and low-income gaps, coastal and inland region gaps) suggests a *diversity and variety* approach to the end-users' sophistication.

ii) The *customer interface* in a multiple-layered market like China – from extremely sophisticated to extremely simple – is characterised by high complexity and may necessitate very sophisticated solutions that bring pressures on innovation, especially for application technologies.

iii) If agglomeration theory has any relevance it must be to the development of Chinese mobile technology. In other words, the networking characteristics of advanced applications and services suggest a *dynamically aggregated user pool* as a prerequisite for certain community-demanding applications. In China's case, with around 400 million mobile subscribers and 110 million Internet users at the beginning of 2006, there seems to be a huge potential to form von Hippel (2005) style "democratized innovation". The 'red flag' Linux system seems to advocate this indigenous effort.

iv) The characteristics of a transitional economy like China may add an additional dynamic phenomenon – *speed of upgrading* – to customer sophistication.

v) It may be argued that the Chinese market measured in real activities is larger than what appears as measured in international currencies. In the still semi-sheltered Chinese economy the cost structure – much lower than in most other countries – has the implication that one gets much more real activity for a given amount of money than in most other countries.

The interviews reveal that this global sourcing of innovative workers can have dramatic effects on Chinese learning and on the development of human skills and capital. The high mobility of current Chinese knowledge workers may be assessed in a context of *personnel training* in an emerging economy. There is also a *returnee phenomenon* ('brain gain'), which seems to be integrated into this globalized knowledge formation process. The *externalities* (e.g. spillovers) created by MNEs' labs are vital for learning and indigenous innovation. Besides personal skills training, we observe also *learning from the organization perspective* on the R&D through to market test. A virtuous cycle of technological capability development is under development.

There is also another side of the coin: the growing knowledge formation within the ICT sector (primarily measured here as R&D) of Chinese actors; domestically within China and internationally as parts of global Chinese R&D strategies. Our previous analysis was based on available statistical data, whereas the following discussion contains our interpretations of interview data. The absolute increase of Chinese R&D in the ICT sector is impressive

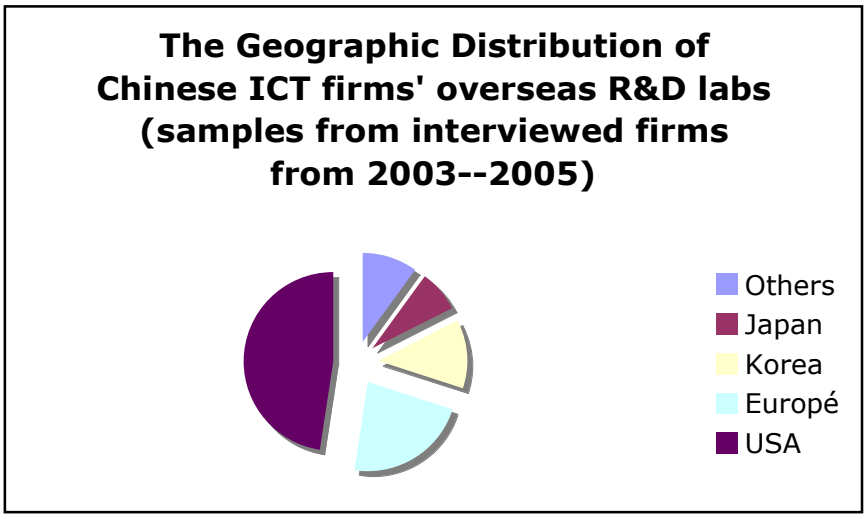
although the sector as a whole still may be classified only as a medium high-tech sector in the OECD classification. Chinese firms still produce – as is far from rare in OEM production – items which to a large extent are developed outside China, which partly explains the low R&D intensity in China. The mirror image of that, of course, is the high R&D intensities in the ICT firms from developed countries. So, the endeavours of latecomers to move up the development ladder and upgrade technology capabilities are clear.

There are increasing R&D activities carried out by enterprises that nowadays start their own labs, something which would have been impossible three decades ago. Many Chinese firms/enterprises actively take the lead in large-scale research projects, for example the development of a Chinese 3G standard, TD-SCDMA. Along with establishing industrial alliances and leading research units at home, a number of booming Chinese ICT vendors strive to become global suppliers and set up R&D labs in the advanced economies. The following firms illustrate this trend: Huawei, ZTE, Lenovo, etc.

The average age of ZTE, Huawei and Lenovo employees is 27-29 years old. Many other Chinese ICT firms have a similar structure of R&D staffs and age of staff. We also tried to get some sense of the locations of Chinese ICT firms' overseas labs based on the semi-structured interviews. Among interviewed Chinese ICT firms, there are 22 Chinese firms having around 40 overseas labs, although their scales vary.

As seen from the chart (Figure 2), Chinese ICT firms' overseas labs are heavily concentrated in the USA and Europe where the current ICT technology frontier mostly lies. However, there are also labs located in emerging economies like South Korea, India and Russia for deploying local advantages.

Figure 2: Geographic distribution of Chinese ICT Firms Overseas R&D Labs



Source: interviews and company data 2003-2005 (22 firms and 40 identified labs)

Based on the information obtained from the semi-structured interviews, we could identify a common path with four steps of Chinese ICT firms' overseas R&D:

i) Business Intelligence (BI) unit,
ii) Cautious (budgeted) expansion & investigation,
iii) A clear technological element/focus formed,
iv) Convergence with local market needs.

Obviously, there have been barriers and impediments for Chinese firms to learn at home. Our interviews reveal that – from a learning perspective – there were failures and bad experiences. The Chinese policy over more than two decades – "technology in exchange for market" – aimed at promoting technological transfer was no real success. Chinese authorities and firms have drawn the conclusion from earlier JV cooperation that MNEs will not actively transfer qualified technologies unless actively convinced or forced to do so. Many reasons lay behind the limited results obtained. There may have been semantic and communicative limitations in the transfer process. There may have been limitations of the absorptive capacity on the Chinese side. In fact Chinese engineers and scientists have to large extent lacked international experience until recently; There has obviously also been reluctance towards technology transfer from the transferor's side; there have been – and still are – political restrictions on technology transfer which have had impacts on firm behaviour. And finally the quite normal behaviour among MNEs is that core technologies are not transferred unless the firms believe they can benefit from the transfer process in the long run. The hitherto low status of IPRs in

China has obviously contributed to a reluctance from MNEs to transfer their technologies and know-how.

Summarizing the above trends, we argue that globalization processes have moved into a third stage: knowledge formation, not only production activities, now take place and are sourced on a global scale. This process not only goes beyond the traditional wisdom on the international division of labour but is also connected with knowledge flows in many directions instead of a one-way knowledge diffusion (transfer) which has been in focus in many catching-up analyses.

3.2 Patenting patterns

We have also tried to grasp the tendencies discussed above from an IPR perspective. Below we focus on how firms in the emerging Chinese ICT industry are building international stakes related to Intellectual Property Rights (IPRs), and manage these in the broader catching-up process. The relevance of the study stems from the significant increase in the importance of IPRs in international competition (see e.g. the Special Issue in *Economics of Innovation and New Technology* (2004)). In the ICT industry the concerns over IPRs are especially pronounced due to the strategic role that patents play in standard-setting. Firms often hold multiple overlapping patents due to technological complementarities, whereby these patent-based IPRs become 'bargaining chips' in, or 'tickets' to, standard-setting alliances between firms (Bekkers et al. 2002; Shapiro 2003). Since the incumbent firms from developed countries especially have acquired large shares of such patent-related IPRs Chinese firms are facing a great challenge as they are endeavour to further upgrade existing knowledge bases and market positions in the global ICT industry.

The literature on IPR management does not really account for the fact that countries and firms enter industries on unequal terms. The fundamental dilemma for latecomer countries stems from the inherent characteristics of knowledge in the ICT field that can be characterised as both 'proprietary' and 'infrastructural' (Steinmueller 1995). As a consequence the engineering community of the incumbents has strong incentives to pool knowledge and related IPRs in their upstream activities, while they also might wish to create entry barriers for new entrants from latecomer countries to sustain their competitiveness in downstream activities. This creates so-called 'IPR thickets', or an overlapping set of patent-based IPRs requiring those seeking to develop and commercialize new technologies or standards to obtain licences from multiple patentees (Shapiro 2003). Latecomer countries and firms therefore might get caught

in a vicious circle and thus face severe constraints even though they possibly able to narrow down other knowledge-related gaps in catching-up with their highly developed competitors (Perez and Soete 1988).

The case of the emerging Chinese ICT industry is especially interesting from a catching-up perspective due to ongoing convergence between data communications and telecommunications, as well as the diffusion of the Internet Protocol (IP), that provides new entry opportunities (e.g. Bohlin et al. 2000). In this context China may be particularly well-placed to take advantage of a heterogeneous and huge-sized home market as a living laboratory to advocate its own technological platforms. This is best exemplified by the development of the Chinese 3G standard TD-SCDMA[7] as well as by the 4G proposal LAS-CDMA.[8] In this sense the situation for latecomer firms engaging in catching-up is now quite different when compared to the single-standard environment of the GSM (Global System for Mobile Communications).

The point of departure of this analysis is that the future rise of China to the forefront of new ICT technologies and markets largely hinges on whether the Chinese ICT firms – a majority of which currently are paying voluminous patent royalties to foreign firms – manage to navigate IPR thickets and in the process create indigenous knowledge bases and IPRs. Given the importance of patenting as a means to protect IPRs in the ICT industry, the empirical part of our work is focused on patent-related IPRs although other means of protecting and managing IPRs are also discussed. With reference to the discussion above, its purpose can be broken down into two following sets of research questions:

1. What is the present position of the emerging Chinese ICT industry in terms of patent-based IPRs in an international context? How has this position changed over time, and how indigenous are these IPRs and the related knowledge bases?
2. Apart from patenting, which other means do they use in protecting their IPRs, and how do they manage these IPRs internally and in collaboration with other firms and actors in China and abroad?

Through these research questions we also discuss whether there is a Chinese IPR profile contextually embedded in its cultural and managerial norms. It thereby also contributes to a better understanding of the extent to which IPR strategies and indigenous efforts affect

[7] TD-SCDMA or Time Division Synchronous Code Division Multiple Access.
[8] LAS-CDMA or Large Area Synchronous Code-Division Multiple Access.

latecomers' catching-up capabilities, as well as how policy may be designed to support the catching-up process of latecomers. Here we focus on the degree to which firms in the emerging Chinese ICT industry are entering patent-based IPR thickets, as well as on how they manage IPRs in the context of this industry and develop indigenous knowledge bases during that process.

The case of China is especially interesting since IPR management and patenting is pivotal due to the pervasiveness of standardization, cross-licensing and patent pooling in response to technological complementarities. However, the large Chinese market combined with indigenous efforts to promote the 3G TD-SCDMA and 4G LAS-CDMA standards imply that China is in a unique position in this context. We place the analysis in a framework that deals with catching-up and leapfrogging processes, while attempting to contextualize IPR management issues from a latecomer perspective. We have combined quantitative analysis of Chinese ICT patenting at the US Patent & Trademark Office (USPTO) with qualitative interviews. In short, there are four main results of relevance both to the further development of the Chinese ICT industry, as well as to a discussion of the changing competitive constellation of the global ICT industry.

i) It seems clear the Chinese ICT firms indeed are entering patent-based IPR thickets as witnessed by an accelerating growth in the number of granted patents at the USPTO, and this trend is underlined further by an equally accelerating growth in patent applications in the most recent years. These patents relate foremost to the more peripheral fields of ICT, namely various instruments and components, even though the core fields of 'Consumer electronics' and 'Telecommunications' also are becoming the targets of patenting. However, the absolute level of Chinese ICT patenting is still very low especially when allowing for the large size of the country. On the face of it, the emerging Chinese ICT industry thus still has a long way to go before it can penetrate patent-related IPR thickets of the incumbents from the developed countries. The qualitative interviews that we undertook also confirm that Chinese firms in the ICT industry acknowledge the strategic importance of building up patent-based IPR stakes to navigate the thickets.

ii) Patent data suggest that the emerging Chinese patent-based IPR stakes are relatively indigenous. Chinese firms as assignees account for the largest and most rapidly growing share of granted Chinese ICT patents at the USPTO. Foreign affiliates also contribute a noteworthy share, while joint ventures with foreign

partners appear relatively insignificant. These insights were confirmed an analysis of the share of inventors with a Chinese affiliation. They were also confirmed by the interviews, although many firms highlighted the importance of re-engineering as an important source of indigenous incremental innovation. Further, the firms recognized the importance of Chinese efforts in standardization as exemplified primarily by the 3G TD-SCDMA standard. Thus, it seems that this standard not only has enhanced the negotiation position of China in standard-setting, it has also contributed to developing an indigenous knowledge base by providing a national test-trial laboratory for next-generation technologies.

iii) Our qualitative analysis provided insights into the motives behind the aspirations of Chinese ICT firms to develop patent-based IPR stakes, as well as develop their IPR management practices in a broader sense. We identified four partly overlapping types of firms in this context. The first is comprised of strong and independent indigenous firms which take the international market as their target also in patenting. The second type consists of firms that seek to enter alliances with foreign firms to gain complementary assets and thus patent in order to gain entry tickets into patent pooling and cross-licensing activities of the incumbents. The third type comprises mainly spin-offs from universities or research organisations that use patents to signal their technological capabilities to attract venture capitalists. The fourth type consists of firms with a history of patent infringements that put a lot of effort into learning the 'rules of the game' in IPR management, and thereby also seek to build up a strong brand in the domestic market.

iv) *Finally, and most significantly*, it also appears clear that Chinese ICT firms resort to other means of protecting and managing their IPRs. In particular, it seems that the rather underdeveloped patent system combined with cultural traits of the Chinese way of doing business is strongly reflected in the IPR management practices of ICT firms. Especially in the case of domestically oriented firms, patenting is considered as atypical behaviour and might be neither cost-efficient nor socially acceptable. Instead secrecy appears more viable as it compensates for unintended spillovers associated with disclosing information contained in patents. Further, Chinese ICT firms appear to value trust (or 'guanxi' as it is called in China) highly, and this can also facilitate various contractual arrangements

between collaborators, thus mitigating the need for patenting. Lead-time advantages and aspirations to move rapidly down the learning curve also appear important, especially as Chinese ICT firms are largely engaged in incremental innovation where learning curves are probably shallower.

These results highlight an interesting duality in the emergence of the Chinese ICT industry. Clearly the largest and most significant firms with the international market as the target, such as Huawei, ZTE, and firms closely involved with the indigenous Chinese 3G standard such as Datang, are in the process of entering the patent thickets due to the leverage that they have in terms of their knowledge base. Meanwhile the firms with a stronger domestic focus appear to follow quite different IPR management strategies to cope with the weaker Chinese appropriability regime that stems from the underdeveloped IPR system. Hence, it seems that incumbent firms also need to apply a dual approach towards interacting with the emerging Chinese ICT industry. The relevance of patent-pooling and cross-licensing of technology in line with international rules of the game is clear in interactions to the larger and internationalized firms, while the building up of trust and local partnerships is pivotal in the interactions with smaller firms in the large Chinese market.

4. Concluding discussion

Though limited in character; our interviews and limited quantitative analyses basically support our initial statement that there is a new phase in globalization. It seems that knowledge formation processes – which are the core activities not only in the catching-up processes for late coming countries but also for the global operations of MNCs – do indeed take place on a globalized level now. In addition, we see clear tendencies that new countries, and new firms, are approaching the very frontier of knowledge formation and learning. Chinese firms source knowledge globally in processes similar to those used by the incumbents in China. Thus, the advanced Chinese MNCs seem to develop similar IPR strategies to the Western incumbents. When they go global, these firms too have to defend their IPRs against the new firms continuously entering the market in China.

Our focus has been on the ICT sector in China. We have seen that learning processes have taken place on an impressive scale and at great speed. We have also found that the ICT sector serves, to a large extent, as a *lever of modernity*, in demanding, fast-growing and complex mass markets as well as among engineers and scientists – it is, in fact, a tool for catching up. Thus there appears to be a strong cultural dimension in this strong modernization process, but we leave the details of that to another study.

The sustainability dimension is also neglected in our study. It should, however, be recalled that the ICT sector is probably among the most sustainable industrial sectors in the Chinese development process. But this again deserves more in-depth research.

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Technical Note

Abstract

Chinese firms are rapidly developing competitiveness at the high end of the ICT industry in general and of telecommunications in particular. This study focuses on the learning mechanisms and catching-up strategies deployed so far, at the firm level and at the industry level. Global sourcing of simple manufacturing and assembly processes, even in high-tech industries like ICT, is not a sufficient condition for catching-up. The capacity to improve the performance of acquired technologies – i.e. the learning and innovation processes taking place after the transfer has been completed – by far outweighs the importance of the transferred technologies *per se*. From the opening of the door around 1979/80, China gave high priority to a leapfrog strategy rather than smoother upgrading through 'the flying geese strategy'. Our study of R&D activities within the ICT sector is primarily interview-based, and it supports the conjecture that there is a new and third mode of globalization, which rests on globalized knowledge formation processes. Western incumbent ICT firms are starting to move more advanced R&D activities to developing regions, and a group of fast-growing high-tech firms from the emerging economies are aggressively building up R&D labs in the advanced economies. Chinese actors are increasing their knowledge formation within the ICT sector (primarily measured here as R&D) both domestically within China and also internationally as part of their global R&D strategies. The future rise of China to the forefront of new ICT technologies and markets largely hinges on whether Chinese ICT firms – the majority of which currently pay huge patent royalties to foreign firms – manage to navigate 'IPR thickets' and in the process create indigenous knowledge bases and IPRs. We have identified four partly overlapping types of Chinese firms in this context. Chinese ICT firms resort to other means of protecting and managing their IPRs than patents. In particular, it seems that the rather underdeveloped Chinese patent system combined with the Chinese way of doing business is strongly reflected in their ICT firms' IPR management practices. Secrecy and lead-time, etc., are thus more significant. However, the advanced Chinese MNCs seem to develop similar IPR strategies to the Western incumbents.

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