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PART II

Case studies

Features and impacts of the internationalization of R&D by transnational corporations: China's case

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In recent years, an increasing number of TNCs have established R&D laboratories and increased their R&D spending in China. This paper suggests that this internationalization of R&D by TNCs can benefit developing countries such as China, although it cannot automatically upgrade the local S&T capabilities. Therefore, China must upgrade, in parallel to FDI in R&D, its S&T competitiveness by strengthening its national innovatory capacities.

1. R&D laboratories of TNCs in China

Since Nortel Networks Corporation and Beijing University of Posts and Telecommunications jointly set up an R&D centre in 1994, the number of TNCs' R&D laboratories in China has been growing steadily. This tendency was especially pronounced in recent years. Statistics collected by the Ministry of Science and Technology show that in 2002, more than 100 R&D laboratories were established by TNCs in China, and by the end of June, 2004, over 600 of the world's best-known TNCs had set up their R&D laboratories in China.

In 2002, the Beijing Municipal Science and Technology Commission carried out a sample survey among 82 R&D laboratories of TNCs. That survey (China, MOST 2002) concluded that:

- many large and well-known TNCs had set up R&D laboratories in China. Of the 82 sample laboratories, 55 had been set up by *Fortune Global 500* TNCs;

[1] The views expressed in this study are those of the author and do not necessarily reflect the views of the United Nations, its Member States, or the Institutions to which the author is affiliated.

- TNCs' R&D laboratories in China were unevenly distributed: metropolises with relatively strong R&D capacities, such as Beijing, Shanghai, Guangzhou, Shenzhen, Xian and Chengdu, were by far the most attractive locations for R&D. According to the survey, 60% of the R&D laboratories of foreign TNCs were located in Beijing, 18% in Shanghai and 6% in Shenzhen;
- TNCs' R&D laboratories were active mostly in high-technology industries, such as information technologies, software and computers (58 laboratories), the chemical industry (9), pharmaceuticals (7) and the automotive industry (5);
- the majority of the parent companies of the 82 R&D laboratories were headquartered in the United States (32), Europe (20) and Japan (18); these three locations together accounted for 85% of the headquarters. The Republic of Korea, Hong Kong (China) and Taiwan Province of China were found to be additional important sources of R&D by TNCs.

TNCs invest increasing amounts of financial resources into R&D in China. In 1999, of the 10 TNCs in Pudong, Shanghai, whose output was in the range of RMB 1 to 6 billion, only four spent more than RMB 100 million on R&D. By 2004, Motorola alone had invested about RMB 1.3 billion in R&D. R&D activities supported by foreign investment are playing an increasingly important role in China. In 2000, the proportion of foreign investment to overall R&D expenditure surpassed that of Germany and Japan; the ratio in China is relatively high in manufacturing (OECD 2003 and China, MOST 2002).

2. Reasons to invest in R&D in China

The boom of R&D is driven largely by the abundant S&T human resources of China. Some TNCs like IBM and Microsoft Research evaluate their R&D laboratories as a

fundamental part of their global R&D activities. The mission of these R&D laboratories is to become an international R&D centre, rather than a support laboratory serving the local market. These R&D laboratories value not only the Chinese market, but also available talents and technological capacities.

The advantages of Beijing and Shanghai in particular, lie in the great number of colleges and universities located there, their large pool of S&T talents and, their well-developed industries.

A second reason to invest in R&D in China is to capture its huge internal market. Serving as a link between the advanced technology of the TNCs and the specific demands of China, R&D laboratories can adapt foreign products and technologies to local needs. For instance, a local R&D laboratory of Matsushita Electric Works adapts the technology of the parent corporation for electrical appliances to Chinese specifications. With that adaptation, Matsushita has gained a good share of the Chinese market.

3. Forms of R&D laboratories in China

The following are the three most common forms of TNCs' R&D laboratories in China.

- The first form is an independent R&D laboratory. This is the most mature, popular and advanced type, and is also the core of TNCs' R&D activities in China. Those laboratories are branches of global R&D networks of TNCs, under the direct management of the R&D headquarters, and are financed by the TNCs. As this kind of R&D laboratory can better protect intellectual property rights, TNCs, attracted by the improving investment environment, tend to establish this type of R&D laboratory in China. By the end of

October 2003, more than 260 independent R&D laboratories had been established by TNCs in China.[2]

- The second is an R&D department, either under a business section or, under a joint venture, or undertaking R&D activities without establishing a specialized department. Many TNCs try to improve their products and services in order to better gear their products to local demand. Motorola, for instance, established R&D departments in the Personal Communications Sector and the Global Telecom Solutions Sector respectively, to carry out specific R&D studies. Moreover, since most foreign affiliates in China are high-technology companies, almost all of these enterprises have their own R&D departments or technology development support companies, in order to ensure normal production and introduce internationally advanced technologies. Foreign affiliates producing software in particular, need a number of personnel to carry out R&D activities; accordingly, they invest in R&D activities, although they do not necessarily have an independent R&D department. This is popular among small foreign affiliates in software development.

- The third form is a cooperative R&D unit with Chinese universities, R&D laboratories and enterprises. A limited number of TNCs subcontract some R&D to local higher learning R&D laboratories and enterprises, taking advantage of their personnel. A survey among foreign enterprises undertaken by the Chinese Academy of Social Sciences shows that 77% of the foreign enterprises had never formally cooperated with Chinese R&D laboratories and 79% of them did not have any plan in this regard.

[2] According to the statistics of the Ministry of Science and Technology.

4. Impacts of R&D laboratories of TNCs on China

TNCs' investment in R&D in China has had a positive impact on the development of human resources, R&D management and on industrial technology. On the other hand, it may have had a negative impact on Chinese R&D laboratories.

a. Positive impacts

First of all, TNCs' investment in R&D has resulted in the development of human resources on a large scale. TNCs emphasize the training of personnel, and regard improving the quality of personnel as a key factor of their competitiveness. Although China has abundant R&D personnel, most of these talents used to end up in higher learning and R&D laboratories to undertake basic research. Moreover, these talents did not meet the demands of the market. TNCs offer them relevant training. This contributes to the development of Chinese human resources and the enhancement of their talents.

Second, R&D laboratories established by TNCs bring advanced R&D management to China. TNCs not only have experience with advanced innovation systems and global innovation networks, but also with developed management systems and methods of R&D networking. Therefore, TNCs' R&D, and the training of local people who have been involved in TNCs' R&D management, can have a positive spillover effect on the R&D management of Chinese institutes and enterprises. In a short period of time, for instance, Microsoft Research Asia developed an excellent software R&D laboratory with a worldwide reputation and, it might be possible to emulate some of the methods used to achieve this.

Third, TNCs' R&D laboratories raise the overall level of industrial technology in China and contribute to the adjustment of its industrial structure. As TNCs' R&D

laboratories are technology intensive, TNCs increase the overall industrial technology level of the economy by carrying on R&D activities and applying for patents in the area of their activities. Their output of S&T development and innovation may give birth to the development of relevant products along the product chain, and also produce spillover effects on product and technique innovation.

b. Negative impacts

TNCs' R&D laboratories can also exert a negative impact on Chinese R&D.

- Chinese R&D laboratories may find it more difficult to hire talent attracted by TNC laboratories.
- There is a risk that State technological secrets might be disclosed to foreign firms as a result of personnel movements and in-depth cooperation with TNCs.
- Some less efficient local R&D laboratories may be forced to close down because of strong competition by TNCs. In cases of calls for public bids for instance, foreign affiliates may be in a better position to win due to their advanced research capability, equipment and management experience. The trend of crowding out local laboratories might increase after China's accession to the World Trade Organization.
- The internationalization of TNCs' R&D alone cannot upgrade China's S&T competitiveness. The level of diffusion of the competitive technology of TNCs in China is still low. According to a survey undertaken by the Chinese Academy of Social Sciences in Beijing, Shanghai, Suzhou and Donguan, 91% of foreign affiliates do not apply for patents, and 13% apply for international patents only. Moreover, most of the TNCs' R&D expenditure is within their own affiliates. In 2002, Chinese universities and public laboratories derived a mere 1% of their resources

from foreign TNCs and their affiliates.[3] From the point of view of the structure of R&D expenditure by foreign TNCs and their affiliates in China, 88% was devoted to business R&D spending, 8% to laboratories and 4% to higher learning (China, MOST 2002). Thus, TNCs' R&D activities in China focus on applications, rather than basic research undertaken by higher learning and governmental R&D laboratories (the relevant technologies that are decisive to national competitiveness on the macro level).

5. Conclusion

In general, China can benefit from the internationalization of R&D by gaining advanced R&D experience and developing its human resources. Nevertheless, a developing country such as China needs to rely primarily on its own forces to upgrade S&T competitiveness. TNCs' R&D activities alone cannot provide the support needed for national and business S&T competitiveness. The enhancement of China's competitiveness lies first and foremost with the Government of China and Chinese enterprises.

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[3] 76% was derived from government sources, 11% from local firms and 12% from other sources. See China, MOST 2002.

International R&D strategies of TNCs from developing countries: the case of China

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International R&D is a by-product of intensified merger and acquisition activity (Gerpott 1995) and more deliberate internationalization of corporate innovation (Bartlett and Ghoshal 1989). Research on the latter has provided information on different typologies of corporate technology activities (Medcof 1997), R&D internationalization strategies (see the special issue in *Research Policy* in 1999),[2] R&D location decision-making (Voelker and Stead 1999), multi-site R&D project management and technology transfer (Chiesa 2000), and intra-organizational technical communication (Katz and Allen 1984). Most of this research — with few exceptions — focused on R&D conducted in developed countries, partly because these countries were responsible for the bulk of global R&D conducted, partly because their protagonists were more easily accessible and forthcoming and, partly because R&D in developing countries was insignificant in scale. For instance, a review by von Zedtwitz and Gassmann (2002) indicates that on average, European firms conduct around 30% of their R&D abroad (half of which in other European countries). The same ratio is about 8-12% for United States firms and no more than 5% for Japanese firms. Data and research on R&D in developing countries is scattered and few. Only a handful of economies outside the developed countries receive some research attention, among them are Singapore, the Republic of Korea, India and, most recently, China.

The principal research purpose of this paper is to shed more light on R&D internationalization by firms in developing

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countries, with a focus on China. First, it assesses the extent of international R&D emerging from developing countries, proposing a 2x2 model of past research on international R&D. Based on research conducted on Chinese technology-intensive companies, strategies and struggles of R&D internationalization are investigated and analyzed. The data seems to suggest that due to their special position, firms from a developing country organize their international R&D activities as both capability-enhancing and capability-exploiting structures. The paper concludes with open research areas and some preliminary implications for research, management and policy making.

1. Research framework and directions

R&D has always been considered a domain of firms in technologically advanced and economically developed countries. In fact, the ten largest countries in terms of GDP also lead in terms of technology-intensity (except for China and Brazil). TNCs account for substantial shares (between 33% to 57%, according to a mid-1990s study reported in Gassmann and von Zedtwitz 1999) of their total national R&D expenditures. TNCs dominate private international R&D investments. Of the 100 largest TNCs in the world (in the year 2000), 94 were headquartered in developed countries, three in China, and one each in Mexico, Venezuela, and the Republic of Korea. Patent applications in the most important markets are led in numbers by large TNCs from the United States, Japan, and Western Europe. Clearly, firms in developed countries dominate domestic and international R&D. (Dunning 1988, UNCTAD 1999 and 2001).

R&D in developing countries has figured less prominently. Most research has concentrated on technology transfer to these countries, and their capacity to absorb advanced technologies from abroad (Kim 1980 and 1997, Lall 1990). Without doubt, the level of science, technology, and innovation has been increasing over the last years but, the

investment ratios of S&T to GDP are still far behind developed countries (see Schaaper 2004, OECD 2002). Moreover, the leading TNCs from developing countries tend to be low on technology-intensity, and concentrate on natural resources such as real estate, oil & exploration, and mining & materials. R&D by the few technology firms in these countries tends to be comparatively weak. Lack of S&T resources and lack of local market demand for sophisticated and expensive technology goods discourage private efforts in serious R&D.

For the first time since the mid-1980s, when international R&D became a more widespread practice among technology TNCs, we are witnessing the emergence of a new class of high-technology companies from developing countries, most notably India and China. These companies compete in highly technology-intensive industries, in which customers demand great rates of innovation and, in which timely application of technical know-how is paramount. They have one thing in common: they are headquartered in large developing economies. They differ from their predecessors in the Republic of Korea and Japan in that they are facing international competition in their home markets, that technological change has accelerated since the 1970s and, that know-how — and the workforce — has become more mobile. In other words, the environment has become more global.

Competition among these companies can be extremely intense, which does not favour internationalization into foreign markets. However, a few companies have emerged that pursue R&D of international calibre nevertheless, such as Embraer in Brazil (the world’s third largest supplier of mid-range aircraft), Huawei (a leading telecommunications firm from China), and Infosys (a global IT services provider in India). The evolution of companies from developing countries, and the development of their innovative capacity has been the subject of recent investigations (Lee et al. 1988, Bell and Pavitt 1993, Sung and Hong 1999, Xie and Wu 2003, Xie and White 2004). However,

the extent to which firms from developing countries develop international innovation capacities and build global R&D networks has not yet been studied in detail. Here too the best explanation is that until recently there were probably a very limited number of firms from developing countries able to undertake such international R&D.

Figure 1 summarizes some of the previous research trajectories in international R&D research. The first type concerns "traditional" R&D internationalization among developed countries, i.e. mostly within the triad countries of North America, Western Europe, and Japan. This area of R&D internationalization has been widely researched, and yielded a very valuable and rich literature as well as a fundamental albeit initial understanding of transnational innovation management. Most of the international R&D flows are covered by Type 1 research, as indicated by the preferred routes of FDI (the Triad countries accounted for 71% of all FDI inflows and 82% of all FDI outflows in 2001). However, the rise of China (and to some extend India) as a principal recipient and source of FDI in 2002 and 2003 has led to a new, "modern" category of research, denoted Type 2 in figure 1. Examples of Type 2 R&D internationalization are IBM's establishment of R&D in India, Microsoft's Research laboratory in China and, Fujitsu's Development Center in Malaysia. This modern form of R&D internationalization became popular in the late 1990s, driven in part by improved economic conditions in South-East Asia, China and Central and Eastern Europe, in part by strategic considerations of parent companies to set global standards and build global brands and, in part by a growing understanding and financial commitment of TNCs to support local sales with local R&D efforts.

Figure 1. Types of R&D internationalization, based on the dates of establishment of international laboratories, early 1970s to 2004

Home Country \ Host Country	Developing	Advanced
Advanced	Type 2 MODERN *(e.g., US → China, EU → India)*	Type 1 TRADITIONAL *(e.g., US → EU, JP → US)*
Developing	Type 4 EXPANSIONARY *(e.g., China → Brazil, India → China)*	Type 3 CATCH-UP *(e.g., China → US, India → EU)*

Source: the author.

Type 3 and 4 in figure 1 denote a novel, so far mostly ignored direction of R&D internationalization. Arguably, researchers such as Lall (1987, 1990) and Kim (1980, 1997) have studied the acquisition and development of technological competencies in developing countries but, the notion of firms headquartered in developing countries establishing R&D capabilities outside their home countries is new. The espoused view was that firms in developing countries were too busy absorbing technology transferred from abroad, and hardly capable to push technological boundaries themselves. They would use their new competitive advantages to defend and build domestic market shares and, if they were sufficiently attractive enough, they would be acquired by much larger foreign TNCs. Some countries imposed policies protecting domestic technology companies, either by making foreign acquisitions more difficult or by curbing competition from foreign affiliates. In any case, the internationalization of business and technology has largely been unidirectional from developed to developing countries.

Figure 2. International R&D units and their classification, based on data collected up to 2004

Home Country \ Host Country	Developing	Advanced
Advanced	Type 2: Modern 194 (25%)	Type 1: Traditional 496 (64%)
Developing	Type 4: Expansionary 22 (3%)	Type 3: Catch-Up 64 (8%)

Source: Based on own research of the locations of 776 international R&D locations (von Zedwitz and Gassmann 2002)

Type 3 describes firms from a developing country conducting R&D in a developed country. Because of their principal motivation of catching up with developed countries, this type of R&D internationalization is labelled catch-up, with examples such as Samsung of the Republic of Korea investing in R&D in Europe, and Acer of Taiwan Province of China in the United States. These firms are naturally attracted to using developed countries as R&D bases, partly in order to acquire local technology and science, and partly in order to support local product development.

Type 4 R&D internationalization is when a firm in one developing economy invests in R&D in another developing country. The reasons for this kind of investment may be in supporting second-generation technology transfer (when the earlier recipient of a technology transfers a technology on to an even less developed country) or, to support other local business activities. An example is Acer's R&D laboratory in China, and Huawei's R&D centre in Bangalore, India.

As can be seen in figure 2, the instances of Type 3 and 4 internationalization are not trivial. Using a database comprising the locations of 1,269 R&D units, 776 locations were identified as international, meaning that the parent company was headquartered in another country. 64 belonged to Type 3 or the catch-up type, while a respectable 22 belonged to Type 4 or the expansionary type (496 R&D units belonged to Type 1 or the traditional type, and 194 to Type 2 or the modern type of R&D internationalization). At least in this database, international R&D from developing countries already constitutes about 11% of all international R&D.

These Types 3 and 4 of R&D internationalization are not well understood and - to some extent - even contradict established views on international R&D. For instance, firms from developed countries invest in R&D in developing countries in order to exploit labour and operating costs advantages. Hence, under what circumstances would a company from a developing firm consider giving up this particular advantage by going into a country with a highly adverse purchasing power parity or, as long as companies from developing countries are still struggling with the incorporation of mature technologies transferred by joint venture partners, how can they assume that they are ready to absorb far more sophisticated technology currently under development in developed countries? Furthermore, these foreign advanced technologies are probably without differentiation potential for firms from developing countries in the more important domestic markets.

With its high GDP growth rate and rapid industrialization of the coastal areas, as well as a growing number of technology-based companies, China provides a very fitting example of a developing country. China also faces many of the same problems other developing countries need to confront, such as a high degree of state control, low purchasing

power of its domestic currency, comparatively low rates of tertiary education and, a lag in developing an economic and legal framework conducive for private business. More specifically, the research presented in this paper pursued the following research questions.

- How significant a role do companies from developing countries, in particular China, play in worldwide R&D? How relevant is this topic for future research?
- What motivates companies from China to conduct R&D elsewhere? What are the push and the pull factors?
- What strategies do Chinese firms employ in order to expand R&D internationally?
- What barriers and challenges do Chinese companies face in doing so that may be more specific to them as being from a developing county?

2. Research methodology

The aim of this analysis was to investigate a well researched phenomenon (internationalization of R&D) in a new environment (China). With this objective, an empirical, quantitative research approach would have been appropriate. However, initial exploratory interviews indicated a low intensity of international R&D in Chinese companies as well as a high disinclination to cooperate in academic research on R&D management. In one of the closest comparables to the present research, Jin Chen of Zhejiang University attempted to study international innovation by Chinese companies but received only 28 valid questionnaires out of 279 sent out (Chen 2003). With response rates this low, and the main focus of the research questions to be qualitative in nature, it was concluded that survey-based research would be ineffective in gathering the information necessary for purely quantitative empirical analysis. Instead, it seemed more fruitful to focus on the top Chinese companies and to conduct in-depth research.

Data for this research was thus collected mostly by personal research interviews, and complemented by database research. Research interviews focused on senior R&D managers in selected Chinese companies, most of which are leading firms in their industry (Lenovo, Huawei, Haier, Kelon, Founder, ZTE, Longshine, China National Petroleum, Datang, Dongfeng, NetEase). Only the first six of these companies operate international R&D units, while the last five did not posses foreign R&D presence at the end of 2004. However, both groups were investigated, as the research objective also included the identification of barriers and challenges of R&D internationalization. Most of the interviews were conducted in late 2003 and 2004. Database and Internet research was conducted by researchers familiar with the Chinese language, thus including the much richer documentation available in Chinese. Research reports were sent back to the interview partners and feedback was requested to correct erroneous interpretations and, to ensure greater validity of the data. In each case multiple sources of information were used to increase the reliability of observations. Although only representing a small selection of Chinese companies, the collected R&D data were compared to an international database of R&D locations and investment hosted by the Research Center for Global R&D Management at Tsinghua University in Beijing.

3. The significance of Chinese R&D internationalization

Most Chinese companies are relatively young (and therefore comparatively small) and focused on domestic markets. A World Bank survey of 1,500 high-technology companies in China found that they averaged only about 600 employees and were between 10-15 years old. Even well-known Chinese TNCs tend to be small: Lenovo, China’s largest personal-computer manufacturer, has a turnover of only 4% of IBM’s (at least before its acquisition of IBM’s personal computer business in late 2004), and Haier, China’s most famous brand (according to a 2003 survey) had sales of $9.7

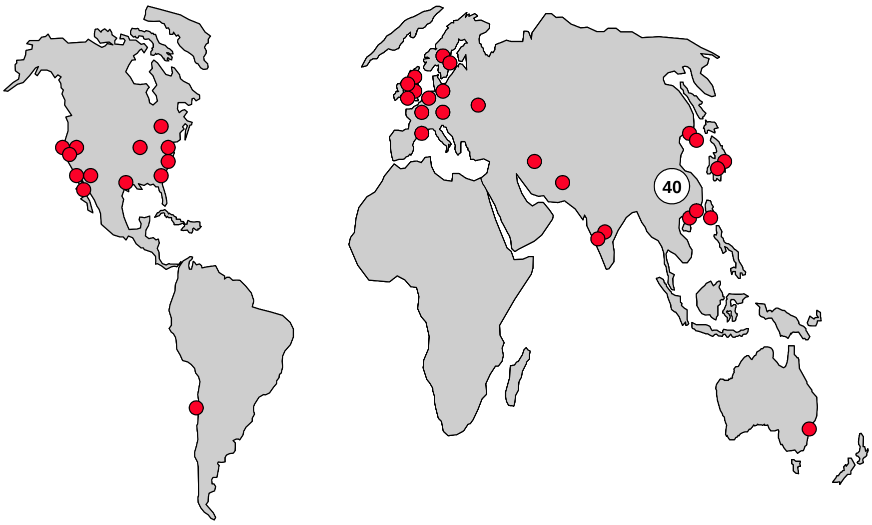
billion in 2003. Furthermore, 50% of the Chinese firms' supply network is located within their cities, and 75% within China, as Ed Steinfeld (2002) notes in his analysis of the World Bank 2001 report. Much of the spending on R&D seems to be directed towards technological learning (Kim 1997), but little of it results in truly innovative products. Rather than building dominance in a particular industry through technological progress, Chinese companies tend to diversify into other sectors in order to exploit economies of scale. As Steinfeld (2002: 14) notes, Chinese "firms focus on activities with low barriers to entry. Once the cost pressures become too intense, rather than moving upward into higher end activities or taking the time to develop proprietary skills, the firms diversify into other low entry barrier markets. The products themselves … are standardized." As a result, most of Chinese R&D is opportunistic and hardly standard-setting.

Given these rather sobering interpretations of the quality of Chinese R&D, what is the scale of international R&D by Chinese companies? Unfortunately, no representative data exists, but an effort was made to get an indication of the magnitude of this R&D using data from other developing countries. Earlier research indicated that at least in developed countries, up to 70% of international R&D was conducted by the top-150 global companies. In an attempt to approximate the volume of international R&D conducted, the author took the fifty largest TNCs from developing countries, eliminated non-technology companies (33 remained), summed up their weighted foreign sales (UNCTAD 2001a), and assumed an average of 2% R&D intensity per firm. Given an average lag of approximately 50% of R&D internationalization behind foreign sales (estimated on the basis of von Zedtwitz and Gassmann 2002), this resulted in a total overseas investment in R&D of about $500 million annually for the leading firms from developing countries. This is equivalent to the R&D budget of a single reasonably sized technology-intensive TNC and hence hardly impressive given the scope of this research.

The Chinese firms in the studied sample operated 77 R&D units, 40 in China and a surprisingly high number of 37 abroad (see figure 3). However, most of these R&D units are quite small in size, with a few exceptions such as Huawei's software laboratory in Bangalore (550 engineers in 2003 and expected to grow to more than 2,000 by 2005). Haier alone operated ten small-scale research units abroad, which focused on technology monitoring and other non-indigenous research activities. The 26 R&D units in developed countries were predominantly located in the United States (11) and Europe (11), and mostly serving as listening post or in product design roles. Japan, with only two Chinese R&D units seems to be somewhat under-represented in this sample, probably due to the small sample size. However, even in the complete database of 776 international R&D units, Japan only accounts for 55 or approximately 7% of total foreign R&D laboratories.

Eleven of those 37 foreign R&D units (just under one third) are located in developing countries, thus falling into Type 4 laboratories (figure 4). Chinese firms account for about half of all international R&D sites owned by another developing nation. Some of these R&D units are extremely small (e.g. there are literally just a handful of people in Pakistan and the Islamic Republic of Iran), but India has attracted quite substantial Chinese R&D investment.

Figure 3. International spread of leading Chinese R&D-intensive TNCs, 2004



Source: information collected by the author.

Figure 4. International R&D of Chinese TNCs in developed and other developing countries, 2004

Home Country	Host Country: Developing	Host Country: Advanced
Advanced	Type 2: Modern 0 / 0 All / Intl	Type 1: Traditional 0 / 0 All / Intl
Developing	Type 4: Expansionary 51 / 11 All / Intl	Type 3: Catch-Up 26 / 26 All / Intl

Source: information collected by the author.

To conclude, even if only physical internationalization of Chinese R&D is considered (ignoring, for the moment, funding of research at non-Chinese universities and participation in international research programmes), China's R&D globalization has already reached a level comparable to some smaller but more developed European countries.

3. Determinants of R&D internationalization of Chinese TNCs

a. Motivation and objectives

"Every multinational will set up in China. Margins are low here. If we don't go outside, we cannot survive" (Haier's chief executive officer Ruimin Zhang, quoted in *The Economist* 2004: 72). Haier, with three industrial parks in the United States, Jordan and Pakistan, ten listening posts in Seoul, Sydney, Tokyo, Montreal, Los Angeles, the Silicon Valley, Amsterdam, Vienna, Taiwan Province of China and Hong Kong (China) and design centres in Lyon, Los Angeles, Tokyo and Amsterdam, is well on its course towards R&D internationalization. A recent addition to their R&D network is a design centre in India, opened in late 2004.

What drives Chinese companies to set up R&D overseas? Given the fact that China itself is a huge and still growing market, most market-oriented R&D is likely to be retained and developed at home. Given also that China still receives a great amount of foreign technology (see Jolly 2004 for the results of a survey of the motivations of Sino-Chinese joint ventures), we can hypothesize that Chinese firms internationalize R&D in order to develop alternate channels of technology sourcing from developed countries – hence, mostly home-base augmenting sites in Kuemmerle's (1997) notation. Automobile manufacturer Dongfeng Motors has established four listening posts in the United States, Germany, the United

Kingdom and France for the purpose of being close to major competitors (not markets) and their technological bases.[3]

Efficiency-driven rationales (see Gassmann and von Zedtwitz 1999 for an overview) such as the exploitation of multiple time zones, the critical mass of R&D, and local cost advantages, hardly play a role for Chinese companies abroad. In fact, many foreign companies go to China because of cost advantages. Hence, Chinese R&D abroad tends to be more expensive than at home, and also less likely to be set up in the first place. However, in cases where Chinese firms operate large manufacturing sites abroad, local R&D has been seen to emerge in support of product localization and process innovation (e.g. Haier's R&D site located with its Camden plant in South Carolina, United States).

While input-related rationales are probably the strongest reasons for Chinese R&D internationalization in developed countries, market and output-related determinants may explain the establishment of R&D in other developing countries such as the Islamic Republic of Iran, Jordan and Chile. Haier prides itself for customer sensitivity. For instance, it developed air conditioners to cope with particularly adverse desert conditions in the Middle East, and designed washing machines that could also handle cleaning vegetables in rural Asia. ZTE's R&D sites in Chile and Pakistan are dedicated to local product adaptation, thus supporting local business development. However, the emergence of R&D in other developing countries is still in its infancy.

[3] Note that Dongfeng recently reorganized itself to become a major 50% joint venture company with Nissan Motors of Japan. The new Dongfeng-Nissan R&D centre in Guangzhou has an investment of $40 million and serves as a platform to combine Japanese automotive technology with Chinese standards and product requirements.

Political, regulatory and governmental factors were not mentioned as having a strong impact on the decision where to set up international R&D sites. However, as more and more Chinese companies develop indigenous intellectual property, foreign companies and states are attacking Chinese companies abroad over their earlier infringements on intellectual property rights at home. As a result, Chinese companies are barred from entry into foreign markets based technologies that they use domestically. Local R&D centres could overcome these difficulties by developing local technology, which, in the process, would build new technological competencies for Chinese firms abroad.

International R&D is often also a consequence of mergers and acquisitions. Although Chinese companies have been more of a target than a source of mergers and acquisitions, this seems to be changing, as shown by the investments of Shanghai GM in GM Daewoo and the acquisition of Germany's Schneider by TCL. Thus, R&D units of acquired companies become part of the Chinese firm's R&D network, often making international coordination necessary.

b. Evolution of R&D

The past two decades produced a number of descriptions of strategies for internationalization of R&D and innovation. Based on Perlmutter's (1969) and Bartlett and Ghoshal's (1989) model of internationalization of organization, Gassmann and von Zedtwitz (1999) developed an evolutionary model of international R&D organization, which fits our purpose of studying the early stages of international Chinese R&D. They describe five types of international R&D organizations: ethnocentric centralized R&D (with a dominant R&D centre serving far-away markets), geocentric centralized R&D (where the R&D centre engages in cooperative projects with customers and other research institutes), the R&D hub (with the R&D centre serving as the central information and

decision-making platform for all global R&D units), polycentric decentralized R&D (of R&D units with little global alignment and coordination) and, the integrated R&D network (in which all R&D units are equal partners and information and decision-making is freely shared).

Companies without international R&D units have either ethno- or geocentric centralized R&D organizations. In the research sample, this is the case for Lenovo, Netease, CNPC and Longshine. Netease, an Internet service company with almost 200 million registered accounts, actually shifted its development centre from San Francisco, California, where it was originally founded, to Beijing and Guangzhou, as the company relocated to China. Most of the technology is imported from the United States, but a large engineering staff writes code and programmes targeted at the Chinese market. Some of its engineers are foreigners who prepare Netease for more global innovation challenges. Other companies have engaged in a number of cooperative projects and alliances, for instance, Lenovo with Intel and Microsoft, and CNPC with Shell and ExxonMobile. They are becoming more open, and hence overcome ethnocentrism for the benefit of a more geocentric outlook.

Moving towards greater physical international R&D presence are companies like Datang, Founder, Kelon and Dongfeng. Datang had some less successful experience of joint ventures with foreign companies such as Lucent of the United States, but have now formed joint ventures with Philips, Samsung, and UTStarcom. It seems on track with R&D internationalization as it explores greater use of its Iranian R&D site. Its chief executive officer has a PhD from a Belgian university and work experience in a Siemens R&D laboratory. Founder recently set up an R&D laboratory in Scotland, which it plans to expand into its new European headquarters. Dongfeng's alliance with Nissan has obvious consequences of

internationalization of product development between China and Japan at the least.

Some companies have firmly established global R&D networks, such as ZTE, Huawei, 3NOD, and Haier. ZTE established its first three foreign R&D centres in the United States and Chile in 1998, and has since founded more R&D laboratories in the Republic of Korea and Sweden. Huawei also has solid international R&D experience. It was the first Chinese company to set up an R&D centre in Bangalore in 2000, earmarking over $100 million for the Indian R&D site, which it expects to serve the Indian subcontinent, West Asia and Africa as strategic markets. With 550 engineers in 2003, it was expected to grow to a staff of 2000 by 2005. Eighty-five per cent of the R&D staff are Indian nationals, as the purpose is to tap into the rich Indian expertise in software design, 3G mobile communications, wireless infrastructure, and network management, etc. Huawei also operates joint ventures with Siemens, 3C, Qualcomm and Microsoft to position itself favourably in the upcoming next-generation mobile communication technology. Almost 46% of its employees are in R&D, although due to the lower labour costs in China, the overall R&D to sales ratio of 10% is more in line with industry averages.

c. Barriers and problems

What are some of the greatest barriers and problems of Chinese companies to expand R&D internationally? In part, they are reflected in typical internationalization problems of companies from developing countries, but some are more specific to China, and some are specific to R&D. Chinese companies face three principal challenges in that respect (Steinfeld 2002).

- They have a size disadvantage: due to their inferior size, they cannot compete head on with much larger TNCs.

- They continue to emphasize local business integration despite increasing international sales. For instance, supply chains are still highly local or regional, and there is little integration with global technology suppliers. As a consequence, Chinese companies are often barred from more value-added activities, and focus on low-cost competition, and hence are unable to engage in product differentiation as a source of competitive advantage.
- They also lack sufficient product innovation. Such innovation would be required for higher profit margins, rather than just reducing costs through efficiency innovation. While simple efficiency innovation produces advantages for manufacturing and customers, it also locks in Chinese companies in mostly domestic-oriented innovation.

Additionally, some companies have to deal with a number of drawbacks relating to lack of resources, lack of experience, and entry barriers in new markets.

- *Lack of cash and resource.*: Although China is an expanding market, profit margins are low and therefore only little can be reinvested in R&D. Investment in groundbreaking R&D (as opposed to technology adaptation and product localization) is more costly, and the first movers are likely to experience a loss of market share. Hence, there is less investment in indigenous R&D , which is the lifeblood of global R&D networks.
- *Lack of management expertise.* Chinese companies have little experience in running or just participating in international companies, and so few of them are qualified for international R&D management assignments. Overseas returnees have been invited to take a stronger lead, but essentially one of the most important phases of corporate internationalization would thus be carried out by outsiders.

There is little efficiency advantage to go elsewhere for R&D as China is already offering a very favourable price-to-

performance ratio for R&D and engineering work. Any local R&D work must be paid for with local revenues, which are generated as local start-up businesses and hence are often reinvested in business development rather than long-term product development.

While younger university graduates speak English better, senior and middle R&D staff have no or little command of English, which is the international language of business and technology. It will take several years before more linguistically trained engineers will have entered the rank and file to support R&D internationalization (incidentally, many of Haier's middle managers are quite young, i.e. in the late 20s).

Chinese management also emphasizes personal networks (*guanxi*) to take decisions and get things done. In international settings, where people are far away from centres of decision-making and corporate networks, foreign R&D managers are at a disadvantage to support their causes and risk permanent loss of social power if removed for too long. Recent initiatives, such as Dongfeng's 'web-enabled R&D systems' are expected to alleviate this problem.

d. Strategies of R&D internationalization

Overall, it seems that truly global R&D in Chinese companies is still far away. Current international R&D structures function because of strong personal leadership or because of a military-style command structure. There is little evidence to suggest that foreign R&D networks managed in this manner are sustainable over the long run, but perhaps we are about to witness the creation of a unique Chinese approach to R&D internationalization. Based on the China example, we can make the following propositions.

- Firms from developing countries are more likely to internationalize R&D into developed countries because of

their shortage of domestic technologies, and because of various limitations to serve foreign markets technologically.

- Firms of developing countries will internationalize R&D into other developing countries opportunistically, i.e. when following local customer requests. As a consequence, they may reap long-term first-mover advantages in less privileged regions of the world.
- Thus, companies with more developed R&D networks create two superimposed R&D networks: one which is innovation capability enhancing, i.e. developing the R&D network's capabilities to understand and conduct cutting-edge technology development by absorbing know-how from developed countries, and one which is innovation capability exploiting, i.e. passing on technologies and technical know-how which has been absorbed earlier and refined for use in other developing countries.

The innovatory capability enhancing/exploiting concept is related to Kuemmerle's (1997) home-base augmenting/exploiting notation, but differs in two important aspects.

- The unit of analysis is the R&D network and its various coordination mechanisms and interactions, rather than a dyadic knowledge transfer relationship between the overseas R&D unit with its home base.
- The focus is on innovation capability and its context-specific actualization, rather than knowledge and information exchanged between R&D units.

4. Limitations

This paper has presented research that suffers from limitations, which ongoing research is trying to overcome.

1. The data set is limited and biased towards a) Chinese companies and b) IT companies. The population size limitation must be solved by systematically screening all Chinese firms of a consistent criterion (e.g. total sales or

total R&D investment). The focus on Chinese companies offers greater in-depth analysis, but limits the potential for generalizing the findings. Similar research needs to be conducted in other countries of similar levels of economic development. The bias towards IT companies is representative of the greater levels of international R&D involvement of Chinese IT companies.

2. The use of R&D units is not a perfect proxy for real R&D internationalization, as a) the average size of R&D units in China may be different from the average size of R&D units elsewhere, and b) the denotation of R&D in China may differ from international usage. However, data on R&D investments and staff deployment are difficult to obtain systematically.
3. With respect to the 2x2 matrix of the four types of international R&D research, the selection of parent companies for inclusion of R&D sites of their international affiliates must follow globally consistent and reasonable criteria. The current data of international R&D locations has been collected using the top companies of developing countries and benchmarking them against top companies of developed countries. Although the latter group is much larger than the former, it must be ensured that companies are considered for the same reason and up (or rather) down to a certain level of e.g. annual turnover or R&D investment. Research is ongoing to compensate for this shortcoming.

This analysis is thus still preliminary, and the suggested findings must be considered in the light of these weaknesses.

5. Conclusion

In this paper, the argument was made that internationalization of R&D from developing countries is rising. Four types – and phases – of international R&D were discerned. As an example of Type 3 and Type 4 R&D internationalization,

Chinese companies illustrated some of the motivations, strategies, and difficulties that such companies face. More research is required in terms of deepening the understanding of Chinese technology-intensive firms' strategies as well as those companies from other developing countries such as the Republic of Korea and India. While this research is still incomplete and the conceptual development ongoing, this paper attempts to offer a new framework to analyze international R&D management research as well as a new perspective on specific management models of R&D in developing countries.

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Technological learning, R&D and foreign affiliates in Brazil[1]

Ionara Costa[2]

Brazil has been one of the main developing country destinations of R&D-related FDI. According to a 2004 survey carried out by the Economist Intelligence Unit (EIU), it was in the sixth position among all countries of the world where TNCs are planning to offshore R&D, and in the third position among developing countries. 11% of the respondents mentioned Brazil, compared to 39% mentioning China and 28% India (EIU 2004). These figures give rise to two questions. (1) What makes Brazil an important site for offshoring R&D? and (2) Why is Brazil lagging behind China and India?

In order to throw some light on these questions, this paper presents some aspects of the technological learning of foreign affiliates located in Brazil and their potential to attract corporate R&D in a context of increasing globalization of such activities. It also addresses how government policies in Brazil have dealt with the technological activities of foreign affiliates.

[1] This paper is based on discussions and studies undertaken at the *Observatory of Strategies for Innovation* (FINEP - OEI/DPP, coordinated by João Furtado, USP/Poli); and more recently, in the framework of a research sponsored by FAPESP on the internationalization of R&D and TNC affiliates in Brazil (coordinated by Sérgio Queiroz, DPCT/Unicamp). The author is grateful to all researchers of the OEI network and to those working in the FAPESP's project, especially to Sérgio Queiroz, whose comments are always constructive. None of them bear any responsibility for eventual errors in this paper.

[2] The views expressed in this study are those of the author and do not necessarily reflect the views of the United Nations, its Member States, or the Institutions to which the author is affiliated.

The point to be made here is that local policies can push further the level of technological learning by foreign affiliates, taking advantage of the process of globalization of R&D.

Foreign affiliates have a solid and strong presence in Brazilian manufacturing. They are amongst the largest firms in the country in terms of value added, employment, new technologies, exports and other economic indicators. The deep-rooted participation of foreign affiliates in Brazilian economic life is the result of a long history of TNC investment.

In Brazil, three major periods of FDI inflows can be distinguished.

- Mid-1950s to the late-1980s: this period was characterized by a strong presence of foreign affiliates, which were instrumental in the process of import substitution industrialization. In technological terms, some adaptive R&D was carried out resulting in minor adaptations and adjustments necessary to better fit imported technologies to local conditions.
- The 1990s, mainly after 1994, were associated with a broad process of *technological upgrading* and *economic restructuring* in response to a much more competitive environment. Technological developments mainly involved the adoption of modern technologies, both of product and process, and new organizational practices, leading to gains in *productivity* and *economic efficiency*.
- More recently, from the late 1990s onwards, there have been signs that a further stage in terms of technological learning is taking place, as TNCs have increasingly included their Brazilian affiliates in their strategies of R&D globalization.

This paper is organized as follows. The next section discusses the characteristics of the third period (the focus of this

chapter), arguing that, in general terms, the main drivers of R&D-related FDI in Brazil include technological capabilities previously accumulated by affiliates, mainly for supporting their productive activities; technological competences of other players in the local system of innovation; and specific technological regimes or sectoral patterns. A subsequent section provides an overview of public policies and their impacts on R&D-related FDI. The last section concludes.

1. Innovation and technological efforts on foreign affiliates

Foreign affiliates are important players not only in the Brazilian productive sector, but also in its system of innovation. In fact, the two dimensions are interlinked. Recent innovation surveys[3] have suggested that foreign affiliates innovate more than domestic firms. For instance, according to a composite index of systematic effort, built up from the data of the "Pesquisa da Atividade Econômica Paulista" on R&D personnel, foreign affiliates were given a score of 20, while domestic firms on average had a score of 6, from a maximum level of 100 (Costa and Queiroz 2002, Costa 2003).[4] This suggests that the technological efforts, particularly R&D, carried out in Brazil are still modest when compared with international levels. Moreover, technological learning and R&D remain at *adaptive levels* (Costa and Queiroz 2002).

[3] Mainly Fundação Sistema Estadual de Análise de Dados, "Pesquisa da Atividade Econômica Paulista" PAEP 1996 and PAEP 2001 (www.seade.gov.br/produtos/paeponline) and Instituto Brasileiro de Geografia e Estatística, "Pesquisa Industrial de Inovação Tecnológica", PINTEC 2000 and PINTEC 2003 (www.pintec.ibge.gov.br).

[4] The maximum level for this index is derived from the "international frontier" (the efforts of United States firms). The United States data are available from the National Science Foundation (www.nsf.gov/statistics).

In view of the globalization of R&D by TNCs and the fact that Brazil has been receiving some FDI in R&D, it is important to analyse whether and how such recent processes can prompt technological learning in the country. Can the trend of globalization of R&D open opportunities for Brazil to move beyond adaptive levels?

In order to clarify this point, it is necessary to look inside the innovation process of foreign affiliates, and learn more about the forces behind the growth of R&D. In the Brazilian case, three factors should be emphasized: production capacity and technological capabilities; specific features of technologies and products; and local competences.

a. Production capacity, technological competences and R&D

It can be argued that there is a strong relationship between production capacity, technological capabilities and the potential to attract R&D (Queiroz et al., 2003). The size of the Brazilian market reinforces this argument, as it has been a driving force behind the R&D activities performed by foreign affiliates. Foreign affiliates with large and long established production capacities are in a good position to conduct corporate R&D, as the performance of productive activities has led to the accumulation of technological competences and skills.

Cases of global product mandates or development centres are mostly observed amongst long established affiliates that have accumulated technological capabilities in some product or process technologies. In such cases, knowledge embedded in local R&D teams represents assets TNCs can exploit in order to consolidate their market positions. As observed by Queiroz et al. (2003), the capabilities of local affiliates serve to complement those of parent firms.

The automotive industry brings some emblematic cases of strong association of production with R&D, particularly “D” (Consoni 2004, Consoni and Quadros 2003, Furtado et al. 2003). For decades, the largest affiliates of carmakers based in Brazil – Volkswagen, GM, Fiat and Ford – have built up significant levels of managerial and technical skills and capabilities, embedded in large engineering teams; and technical facilities, like styling and prototype centres, laboratories and proving grounds (Queiroz et al. 2003).

The activities of technological development by car makers in Brazil have been focused both on adaptations to local and regional conditions, and the development of local derivatives from global platforms. This process of market-oriented R&D has come to be known as *tropicalization* (Queiroz et al. 2003).

Some affiliates of car makers have been able to move forward in the development process (Consoni 2004). For instance, the engineering team for product development of General Motors Brazil was engaged in the development of the sub-compact model Celta. More recently General Motors Brazil proposed to its headquarters the concept of a global derivative based on the new Corsa, the Meriva model. General Motors Brazil was in charge of the coordination of all stages and teams of the Meriva project (Consoni and Quadros 2003). A similar example is the Tupi project of Volkswagen Brazil, which consisted of the development of a derivative based on the new Polo platform, the Fox model. The Volkswagen Brazil product engineering team, composed of around 700 engineers, was in charge of this project. Furthermore, it has received both the production and development mandates for an entry-level model for the global market (Queiroz et al. 2003).

Therefore, “(…) there has been a change on the quality, complexity and responsibility of the activities the Brazilian

engineering has carried out, about to qualify some of the local affiliates to play a major role on global DP [product development]. The tacit knowledge acquired and incorporated by the Brazilian engineering [team] has been an important differential in this process" (Consoni 2004: xv).

In general, the competencies accumulated by local affiliates allow them to compete with their sister companies based in other countries for assignments of R&D activities. The disputes amongst affiliates around the world for roles in the TNCs' network seem to be a relevant aspect of the process of globalization of R&D. Individual countries' systemic capabilities can play another important part in these situations, helping to define for instance, which affiliate will "win" a new R&D laboratory.

b. Technological capabilities and local systems of innovation

While the automotive industry illustrates the case that technological activities by foreign affiliates have been mainly driven by the level of learning they have reached along with their productive activities, the telecom equipment industry sheds light on another important factor: the systemic capabilities, that is, competencies and skills accumulated by other players in the system of innovation. This is reflected in the number of partnerships with universities and research centres. This observation helps to explain the geographical concentration of telecom equipment suppliers in the region of Campinas, in the State of São Paulo. In this area, during the period of state monopoly, competences in telecom technologies were developed in institutions like the Telebras R&D centre (CPqD), and in the State University of Campinas (Unicamp) (Gomes 2003, Queiroz et al. 2003). Nowadays, Campinas has a sound knowledge base for software development and telecom technologies, and a highly qualified workforce in these areas. In

fact, "software development is the most important competitive telecom segment in Brazil (…)" (Queiroz et al. 2003: 13).

In some cases, these competencies were developed by domestic firms, many of which were taken over by TNCs in the 1990s during the privatization process. For instance, Zetax and Batik, both domestic firms with strong development capabilities on small switches, were acquired by Lucent in the late-1990s (Galina 2003). As observed by Galina and Plonski (2002: 12), "[s]ince the headquarters of the company [Lucent] did not have this kind of product [small switches], the Brazilian subsidiary is now the world R&D center of this technology". Therefore, it can be claimed that technological competences in some niches can help local foreign affiliates to take part in the global R&D networks. These niches depend to a large extent on the particularities of technologies and products. For instance, "small switching systems are most used in small towns or neighborhoods and it has good potential, especially in developing countries" (Galina and Plonski 2002: 12).

c. Finding niches: technology, product characteristics and local adaptation

The kind of product and/or the sort of technologies are other important factors that help to explain the room for local performance of R&D activities by foreign affiliates. It is not only the need for adaptation of technologies to local conditions, but also the need for taking into account particularities of the local and regional markets into the process of development, and/or the creation of new products that provide room for local R&D activities.

The automotive and telecom industries are both good examples of this. In the automotive industry the importance of taking into account the preferences of consumers during the various stages of conceptualization and development of a new

model has been crucial for market success. It helps to explain why the carmakers changed their strategies in terms of product development, giving more room for local engineering teams. In the telecom equipment industry the fact that there are distinct technical patterns in different locations (like "Code Division Multiple Access"/"Time Division Multiple Access", "Global System for Mobile Communications"), both in fixed and mobile technologies, imply the need for local development (Galina 2003). In some cases, different generations of a technology may also open some opportunity for local affiliates. For instance, Ericsson Brazil assumed the development of the second generation of "Code Division Multiple Access" focused on the regional market, while Ericsson United States (San Diego) could concentrate on the third generation of such technologies (Galina 2003).

The pharmaceutical industry is another interesting example, albeit in the opposite direction. As drugs are basically global products, and the development of new drugs is a time consuming and expensive process, local R&D activities by foreign affiliates are almost non-existing. It is worth mentioning that while pharmaceutical TNCs have had productive activities in Brazil for more than 50 years, the competencies they have accumulated along the productive process seem to have contributed little to local technological development.

As illustrated by the examples above, a clear view of the specificities of each industry and segments within them is required in order to better understand the position of foreign affiliates in the globalization of R&D and their potential for moving further in this process. Likewise, it is helpful to comprehend how government can play an active and strategic role in this process.

2. Host-country policies: some lessons from previous experiences

The fact that foreign affiliates constitute a crucial part of the Brazilian innovation system makes the case for elaborating strategic and active policies in order to target new foreign investments into more complex activities, like R&D, and induce already established foreign affiliates to strengthen and deepen their local technological capabilities. How can local policy influence TNCs in terms of their global R&D strategies? The failure or success of previous local policies help to clarify this question.

Since the period of import substitution, Brazilian policies towards FDI have been mainly focused on production capacity building and modernization. Further technological learning has not been a major concern, as attention is concentrated on the amount of FDI into the country rather than on the kind of TNCs' activities attracted.

However, over the past half decade, the debate on the role that foreign affiliates play in terms of technological development seems to have been taking on a new direction. Both scholars and policy makers have been increasingly interested in how activities with greater potential for higher added value can be developed. TNCs have been considered important agents in this respect for two main reasons: first their potential to export, second their better position to carry out R&D and engineering activities. The underlying argument is that the more foreign affiliates based in Brazil are deeply integrated into global R&D networks the higher the value they add locally. This argument is behind the new industrial, technology and foreign trade policy, named as PITCE, which

was launched in March 2004 and focuses on innovation, and technological development and foreign trade (PITCE 2003). [5]

Having focused on R&D performed by foreign affiliates (and then on the process of globalization of those activities), this paper now turns to related issues, in order to find out to what extent they helped (or not) to define the technological activities carried out by foreign affiliates. Once again, the automotive, telecom equipment and pharmaceutical industries are illustrative cases.

Regarding the auto industry, local policies have supported the productive and technological dynamic. The *Brazilian Automotive Regime* launched in July 1995 played an important part in stimulating product development by local foreign affiliates. However, this policy was not concerned with R&D investment by foreign affiliates. Its focus was mainly on attracting new investments, increasing production capacity, upgrading products and manufacturing processes and, reaching a broader and deeper insertion of Brazil into the global economy (Furtado et al. 2003; Queiroz at al. 2003). Thus, fiscal incentives were given without any conditionality in terms of local technological development.

Differing from the Automotive Regime, the *Information Technology Laws* ("Leis de Informática": Law

[5] The interest of policy makers in the process of globalization of R&D has been increasing. For instance, in some of the preliminary seminars (in March 2005) for the Third National Conference on Science, Technology and Innovation held in October 2005, organized by the Ministry of Science and Technology Policy, there were debates on "R&D by TNCs in Brazil" (4th seminar, March 2005), and "Globalization of R&D: opportunities for Brazil" (5th seminar, March 2005). It is worth mentioning that the PITCE is the background for all debates in preliminary seminars and in the conference itself (see http://www.cgee.org.br/cncti3).

8248/1991, Law 8387/1991, Law 10176/2001, Law 10664/2003, and later Law 11077/2004) explicitly emphasize technological development (Queiroz et al., 2003). In order to be eligible for fiscal incentives, firms are required to carry out R&D investments and, establish partnerships with local universities and research centres (Galina 2003; Roselino and Garcia, 2003; Roselino, 2003). Moreover, the *Information Technology Laws* were complemented by a traditional policy on local content for telecom equipments, implemented by BNDES (the National Bank for Economic and Social Development). In order to receive financial support from BNDES, telecom carriers have to buy locally produced equipment (Furtado et al. 2003).

It is worth mentioning that the PITCE appears to reinforce the technological trajectory in the telecom equipment industry, as software and semiconductors are amongst the five industries it targets. In this sense, the new *Information Technology Law* (Law 11077) launched in December 2004 is an important step, since it is explicitly concerned with where technological development takes place; when the development is locally performed, the fiscal incentives are higher.

In the pharmaceutical industry there has been a clear health policy in terms of enlarging the production base of generic drugs. However, no gains can be observed in terms of local development of technology. In spite of a sound local production capacity, pharmaceutical TNCs appear to have no investment plans for more sophisticated activities by their Brazilian affiliates. “After all, generic drugs are practically commodities that do not require a substantial technological effort” (Furtado et al. 2003: 117). It seems that the PITCE is not changing this orientation, as the pharmaceutical industry has been defined as a priority industry having in mind not local technological development but, the health policy and local production of currently imported drugs.

These three examples reinforce the argument made in this chapter that local policies can play a role as far as R&D activities by foreign affiliates are concerned. The challenge is to learn about the innovative profile of different agents within the local system of innovation, perceiving their technological strengths and weaknesses. In the case of foreign affiliates, it is important to understand the forces behind the role they have played in the global R&D networks.

3. Concluding remarks

Relying on three industry cases, this paper has shed some light on the technological dimension of activities conducted by foreign affiliates in Brazil, in order to have a better understanding of the position of the country in the process of globalization of R&D. Three factors are emphasized here: previous accumulation of capabilities within foreign affiliates; competencies within other agents of the local innovation system; and characteristics of technologies and products. It also outlined some characteristics of local policies, and concludes that they have an important part to play in this process.

The position Brazil has occupied in the globalization of R&D by TNCs can be explained in terms of market reasons. Two related dimensions are stressed: first, the importance of the large size of the Brazilian market and second, the level of technological capabilities accumulated by foreign affiliates that can be exploited by their corporations. Both dimensions define a market-oriented feature of the FDI-R&D related flows into Brazil, as illustrated by the automotive industry. R&D facilities are mainly established in order to support productive activities. Cases of stand-alone laboratories are almost non-existent in Brazil.

Moreover, both the telecommunications equipment and the pharmaceutical industries point to how government policies play a role in the process of globalization of R&D. While in the telecom equipment industry government policies have helped to make Brazil an attractive site for offshoring R&D, in the pharmaceutical industry they have been passive. Public policy can be effective in attracting FDI-related R&D-if combined with prior accumulation of capabilities, and/or a good human resource base, good quality universities and research institutes and further local development.

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Globalization of R&D and economic development: policy lessons from Estonia[1]

Marek Tiits, Rainer Kattel and Tarmo Kalvet[2]

Ever since the evolution of Italian city-states during the Renaissance and the Dutch and German cities in the 16th and 17th centuries, the concept and success of a modern economy have been based on geographical borders that make specialization possible, i.e. allow for the creation of economic clusters enhancing welfare. Economic theory has been based upon the principle stated by Adam Smith, according to which there is a positive link between welfare and the size of a market, because a larger market allows for greater specialization and thus also contributes to the increase of productivity and improvement of living standards (Smith [1776] 1991, Young 1928).[3]

Recent advances of ICT and the liberalization of markets and trade have significantly changed the meaning and role of geography and the proximity of markets. The value chains of the global economy are no longer formed in line with geographical or national borders, but more and more within particular industries. At the same time, an increasing number of economic units are being established and positioned in the states and regions where the socio-economic environment is the most suitable for the production system in question. This means that simpler production tasks are transferred to regions with lower labour costs, but still of relatively high productivity, whereas more complex, higher value-added activities remain in

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[1] This paper is based on Tiits et al. 2005.

[2] The views expressed in this study are those of the authors and do not necessarily reflect the views of the United Nations, its Member States, or the Institutions to which the authors are affiliated.

[3] Most of the early development economics is based on the same assumption; see Nurkse 1953.

countries with higher living standards. The situation has become increasingly complicated for the regions that can offer neither knowledge-based activities nor low relative labour costs.

In this context, both the enhancement of the competitive advantages of indigenous companies and the selection of locations for FDI are based increasingly on particular economic and technological factors. This makes part of the traditional policies and strategies supporting economic development obsolete or, leaves them without the intended impact. Yet it is obvious that a target of public policies should still be to support the modernization of the economy based on a vigorous private sector.[4] No wonder that the European Commission considers the implementation of the Lisbon Strategy[5] as the highest priority of the EU. However, the Lisbon Strategy does not provide the specific list of the individual steps member States should take in order to accomplish quickly the established objectives. Such detailed regulation does not and cannot exist, because the situations of different European countries are different.[6]

[4] Ever since David Ricardo ([1817] 1821), the prevailing idea that a company operating in a particular location should first of all commit itself to activities where the existing environment offers some advantages has remained. However, modern economic theories do not consider such advantages spontaneous; instead, the business environment created by the State has the decisive role in the formation of specialization (Romer 1986).

[5] A ten-year strategy of the EU to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion.

[6] For theoretical foundations, see Rodrigues 2002. See also the website of the European Commission: http://europa.eu.int/comm/lisbon_strategy/index_en.html.

1. EU membership and economic development

Estonia joined the EU in May 2004 and found itself in a new economic policy environment. Going beyond the transposition of the *acquis communitaire*, Estonia's economic convergence will require a development strategy supporting a more dynamic specialization of the country in the common market. In many respects, the macroeconomic situation environment of Estonia is already similar to that of the older 15 countries of the EU. After the forthcoming introduction of the euro, supervision of monetary policy will be transferred to the European Central Bank, while the Stability and Growth Pact of the EU will establish limitations on fiscal policy. The competence of the EU also includes agriculture and foreign trade, including the application of a customs union towards third countries. For the EU as a whole, such a situation leads to an enormous challenge to develop the economic environment in a manner that is simultaneously appropriate for member States at very different stages of development and, for industries with highly different development trajectories and international networks.

What might Estonia's specialization within the EU be in ten years time? The developments of the past decade will by and large determine the technological and industrial structure of the Estonian economy in the next five to ten years. In Estonia, as in the other Baltic States, most growth has been generated through efficiency gains produced by one-off structural adjustments, privatization and the closing down of unprofitable ventures. An analysis of the development of Estonia since mid 1990s demonstrates that the technological structure of manufacturing has not become more knowledge-intensive or complex, rather the other way round (Tiits et al. 2003).[7] Together with some other new EU members, Estonia is

[7] Similar developments have been observed across Central and Eastern Europe; see Watkins and Agapitova 2004, Havlik et al. 2002.

competing for FDI projects with China, India, Latin American countries and the Russian Federation (Reinert and Kattel 2004).

Until recently, relocation of certain parts of the relatively labour- and/or resource-intensive production has been one of the main motivations behind decisions to invest in Central and Eastern Europe.[8] In most cases, foreign affiliates have outperformed domestic enterprises both in terms of knowledge intensity and sales (Damijan et al. 2003). Positive spillovers from FDI however have been relatively limited. Looking at the structure of exports and the competitiveness of manufacturing, it appears that while the other Central and Eastern European countries specialize in various medium-technology activities, Estonia has until now exclusively specialized in timber processing (including furniture, print and paper industries),[9] and certain low-value added activities of Northern European IT and electronics firms.

The sustainability of Estonia's specialization on timber – a resource-intensive and relatively low-technology industry – is far from granted. Nor would it be reasonable to return to Soviet-era light industries or mechanical engineering. Instead, Estonia would need to gradually expand its presence in the medium- and high-technology industries of the next generation, i.e. in the value chains of IT, biotechnology and nanotechnology. The development of such new industries would need to be linked to the existing economic structure and specialization of Estonia. Otherwise the contribution of new high-technology industries to the improvement in living

[8] Several authors have concluded, that the interest of foreign investors has been more to exploit, and less to develop local resources (Johansen 2000, Männik 2001: 216).

[9] The Estonian timber processing industry is part of the Scandinavian forestry cluster. Over the past 10 years, it has become the most important source of productivity increase in Estonia (Havlik et al. 2002, Stephan 2003).

standards in Estonia would remain only modest, irrespective of the success of individual companies.[10]

In Estonia, the creation of new jobs is directly dependent on the existing knowledge and skills of the labour force and the compatibility of the education and research system with technological developments in the world and in the Estonian economy. This implies that policies aimed at the continuous modernization of industry and the education and research system which, owing to the logic described above, would need to be industry-specific and, at the same time well coordinated. Whilst the establishment of an efficient system of vocational education, advanced training and retraining and the increase of resources for R&D are equally crucial for the creation of new jobs, none of the aforementioned elements is capable alone of inducing the structural changes in society that are needed for a transition to a knowledge-based economy.

2. Main issues

a. Structure of education and science

Whereas the nominal educational level continues to be relatively high, Estonia has relatively limited lifelong learning, i.e. the renewal of people's skills and knowledge in line with the changing needs of society. While the economy has undergone drastic structural changes, the structure of education and science has evolved de-linked from economic changes. The public R&D funding system as it stands today tends to reproduce past activities rather than contributing to the creation of new ones (Nedeva and Georghiou 2003).

[10] Such developments can now be observed in the IT and electronics industries of Estonia and Hungary, where foreign affiliates dominate exports, yet their contribution to the value added remaining in the country and, accordingly to the improvement of living standards is more modest (Kalvet 2004).

At the level of general principles, Estonia has in recent years fully embraced the goals of European innovation policy. However, in practice changes have been slower. R&D and innovation policies usually follow a linear approach to the role of knowledge (including scientific research) in socio-economic development, based upon the belief that massive investment in basic research and the resulting technological development would almost automatically lead to the efficient development of the economy. However, that model that once enabled several technological breakthroughs for world powers (Bush 1945) is not necessarily applicable to small or medium-sized market economies facing resource constraints (Freeman 2002, Nature 2004).

In Estonia, notwithstanding the high rate of unemployment that amounts to as much as over 20% among people under 24 years of age, companies have unremittingly pointed out problems of finding suitably qualified labour (Jürgenson et al. 2005). At the same time, as a result of demographic changes, the number of young people graduating in Estonia from secondary and vocational schools will drop from the year 2008. Since demographic challenges are similar practically everywhere in Europe, severe competition can be expected from better qualified immigrants (OECD 2004: 37, Kauhanen and Lyytinen 2003).

When considering an increase in public investment in education and science, Estonia would first of all need to make the strategic choice regarding in which industries it desires to take the lead, in which industries it would be important to participate actively in EU-wide R&D projects and, in which industries Estonia would want to sustain a minimum level of competence. In addition, modernization of the system of (higher) education in a small country with an aging population requires both the immigration of qualified persons and, a willingness to become an exporter of high-level training.

b. Preferential treatment of IT, bio- and material technologies

Although priority to *IT,*[11] *biomedicine*[12] *and material sciences* has been clearly established in the Estonian research and development strategy *Knowledge-based Estonia 2002-2006* (RTI 2001), no R&D programme has been initiated yet in these areas, nor are there in place any R&D or innovation policy measures targeting these industries. Prompt action would be required in the development of human resources and the economic environment of these areas if Estonia would like to maintain or increase its living standards in the long run. For public policy to be effective, the establishment of priorities must be followed by corresponding substantial changes in institutions and financing.

c. Low private-sector investment into R&D

Having drawn on the lessons of successful Finnish policy in the 1990s, *Knowledge-based Estonia 2002-2006* stresses the importance of the practical application of science. However, as the current structure and competitive advantages of the Estonian economy are more similar to those of Finland in the 1970s and not in the 1990s, the policy of contemporary Finland cannot be directly applied in Estonia.[13]

[11] In the OECD countries, more than half of the increase in productivity is derived from innovation in IT and its application. The IT revolution has not ended with the extensive spread of personal computers and the Internet. When it comes to the economic effect of ICT, the actual revolution is likely to be only beginning (Perez 2002).

[12] Massive investment in recent years into bio- and nanotechnologies and new energy technologies in the United States, Western Europe, the Republic of Korea, China and many other countries increases the probability that these industries will in the coming decades experience breakthroughs that will radically change the world.

[13] In the 1970s, massive investments were made in forest-related Finnish industries (including pulp and paper), making the country one of the world’s technological leaders in that industry.

Due to the structural problems of the labour market, Estonian companies are short of workers with much lower qualifications than required for proper R&D. At the same time, because of the current investment based phase of development of the economy and the small size of the country, R&D *per se* is not the primary source of competitive advantages or motive for Estonian economic development. It is rather the rapid application of various innovative technologies created elsewhere that prompts Estonian development (Kurik et al. 2002).

In the business enterprise, innovation is *almost always* about novel applications of existing technologies, knowledge and skills. As far as economic development is concerned, the issue is not so much the limited investment of the public sector in R&D, but literally the cost of new technologies and knowledge that Estonian companies need to purchase. Here, it is clear that while the market and competition set the limits of risks, it is the role of public policies to lower those risks for a majority of enterprises and, to create an additional stimulus for the renewal of their competitive edges.

Unfortunately the Estonian education, science, technology and innovation policies are relatively weak on assisting structural change in the economy or supporting technology transfer for upgrading traditional industries. In a market economy, it would be still the task of the state to design an institutional environment suitable for balanced socio-economic development. Consequently, for a substantial part of the Estonian private sector, R&D and innovation are just too expensive and risky.

d. Role of FDI in R&D and innovation

In a small country with an open economy the role of FDI is inevitably large. FDI can substantially strengthen the economy through spillovers and transfer of knowledge to

existing industries and, more importantly, initiate the creation and development of new high-technology industries. These roles of FDI have been acknowledged only to a certain degree in Estonian public policy. Little attention has been paid to what motivates investors to invest in Estonia, including in R&D. An overall reduction of the tax burden alone would not be enough. Such a policy could even inhibit the increase of knowledge-intensity of the economy (Bhattacharya et al. 2004, Buffet 2003).

Being a small country, Estonia lacks resources for R&D to the extent necessary to ensure the creation of new international corporations and high-technology industries through spin-off business. However, Estonia can learn from the success achieved by Finland, Ireland, Switzerland and Singapore as a result of a purposeful engagement of FDI in the modernization of the economy. Furthermore, investment by the State in the development of human resources and local competitive assets plays a crucial role in attracting the "right type" of FDI.[14]

Countries such as Estonia would need to exercise caution when developing new high-technology industries, since the development of some science-based industries (e.g. bio- or nanotechnology) alone may not have any immediate effect on living standards. Such high-technology industries are not necessarily connected to the rest of the economy, thereby limiting the value-added created in Estonia. In order to preclude such developments, it is very important to ensure the transfer of knowledge and skills into more traditional spheres that dominate the economy.

[14] In that broader context, the success of the Finnish firm Nokia could be due more to "luck" than "regularity" (van Beers 2003, van Grunsven and van Egeraat 1999).

e. Design and coordination of public policy

Even though *Knowledge-based Estonia 2002-2006* is an important strategic document, Estonia today mostly lacks a political and administrative mechanism that would ensure the actual transition of the Estonian economy toward greater knowledge intensity. A regular evaluation and coordination of policies in education, employment, research and development and innovation is almost non-existent. Therefore, practically no one has an overview of the impacts, weaknesses or strengths of the existing policies. As a result, public policy is not sufficiently balanced and lacks a specific goal as regards the improvement of competitiveness (Estonian State Audit Office 2003 and 2004). The connexion between public policies and the problems of the real economy is rather weak. Estonia lacks policy measures that would enable the State to deal with the factors inhibiting the growth of productivity of companies in the timber, electronics, chemical or engineering industries, i.e. industries that currently dominate the economy and exports or, to specifically contribute to the creation of new high-technology industries.

Although policy coordination is a task of the Government and the Prime Minister, policy-making suffers to a large extent from the lack of an interim level of administration that would coordinate the implementation of general horizontal strategies (like *education, research and development, and employment*). This has resulted in conflicting approaches between different sectoral activities. Very few long-term priorities have been set for education, research and innovation policies. However, it is obvious that the more general the public policy measures, the less they are effective.

There would be a need to redesign the system of public policy-making so as to ensure the coordination of policies aimed at a longer-term perspective and the regular analysis of the impacts of such policies. The elaboration of National

Development Plans for the application of the EU Structural Funds could give an impetus to general policy coordination. Yet more needs to be done to achieve better synergies between education, R&D and innovation policies.

In summary, in order to facilitate Estonia's development, a cluster-based strategy for the enhancement of competitiveness would be needed. That strategy could be based upon strategic road maps for particular technologies and economic clusters, while taking into account possible developments both in new high-technology industries and, in the traditionally significant industries (e.g. energy, agriculture etc.). The definition and implementation of such a strategy could only happen through cooperation between scientists, companies and policy-makers aiming at the enhancement of the competitiveness of a particular cluster through the application of essential technological developments (Porter 1990, OECD 2001).

3. Policy recommendations

a. Technology programmes for the enhancement of the competitiveness of economic clusters

In principle, the public sector of Estonia would need to resolve the question of how to ensure that the private sector's problems are properly taken into account in the design and evaluation of policies. A system needs to be established whereby the State can receive feedback on the actual development of the private sector and technology on a continuous basis. To that end, a system of consistent monitoring of industries needs to be created. The establishment of such a system could be one of the key components of a future development strategy. Such a system of design and coordination of policies could highlight as priorities for the five or six economic clusters that are most essential for the technological and socio-economic development of Estonia (e.g. the timber

and forestry cluster or, the IT and electronics cluster etc. which in terms of value chains, in the aggregate cover the bulk of the economy).[15]

In practice this means the establishment of permanent working groups of the private and public sectors, the tasks of which would include the production of regular overviews of the possible future developments, current problems and alternative solutions thereof in specific industries. These working groups would need to participate in the coordination, design and evaluation of industrial, educational, science and innovation policies. In the current institutional structure of Estonia, such working groups could logically operate within the field of administration of the Prime Minister and the Research and Development Council.[16]

The primary practical output of the working groups could consist of the development and subsequent evaluation and continuous modernization of the technology programmes that are essential for the development of the clusters in question. The programmes to be created could range from new curricula to schemes aiming at involving foreign affiliates and their parent companies, thus creating:

- new industries where Estonia possesses strong R&D potential in the EU context;
- R&D activities that are connected with real economic activities;
- R&D activities that are interdisciplinary; and

[15] As a final outcome, it would be logical to launch national R&D programmes in the fields of administration and by way of cooperation between relevant ministries so as to support the implementation of the relevant industry-level development strategies.

[16] Since the Estonian economy has been rather closely integrated with the Baltic Sea region, that system should also engage the foreign affiliates of TNCs from other Baltic and Northern European countries operating in Estonia.

- R&D activities that are based on cooperation between local and, if necessary, foreign centres of excellence.

b. Horizontal measures

In addition to the commissioning of cluster programmes, Estonia could concentrate on the following four lines of action:

- attracting talented people to work in Estonia and creating an attractive environment for them;
- supporting the transfer of knowledge and technology from foreign affiliates to domestic manufacturing and service industries;
- supporting TNCs and their local affiliates in the fields of R&D and innovation, including reciprocal opening of R&D programmes in the Baltic Sea region and beyond;
- enhancing the capability of companies to apply knowledge created abroad and the capability of scientific research establishments to create new (exportable) knowledge, including training and advanced training; basic research necessary for being current with global scientific and technological developments and, ensuring the required level of the education system.

4. Conclusion

Globalization provides ample opportunities for a more efficient international division of labour, thus contributing to a rise in living standards. The benefits of opening up markets depends on the policy measures implemented in individual countries in response to the strong pressures created by globalization to change existing specializations. There is a role for the State to play in creating positive externalities that would allow domestic enterprises move gradually to more knowledge-intensive, higher value-added activities. Labour, education and innovation policies, focused on some key technologies and

supported by industrial policies, can potentially allow for structural changes in the economy, increase innovative capacities of the industry and, finally raise living standards.

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