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Hierarchical Segmentation of R&D Process and Intellectual Property Protection: Evidence from Multinational R&D labs in China

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Running short title: Hierarchical segmentation of R&D process and IP Protection

Abstract:

This paper examines how multinational corporations (MNCs) protect their research and development (R&D) activities that are conducted in weak intellectual property rights (IPR) regime countries. Findings from a small scale survey and three case studies in China show that hierarchical segmentation of R&D process can be an effective way for MNC R&D labs to protect their intellectual property. Furthermore, a modular R&D structure seen in many IT companies can facilitate this hierarchical segmentation. A center-peripheral R&D organizational structure of MNCs thus appears in the era of globalization of R&D.

Keywords:

Intellectual Property Protection, Innovation, Multinational Corporation, Globalization of R&D, Hierarchical segmentation, China.

1. Introduction

The trend of globalization of R&D has evolved to a stage characterized by multinational corporations' (MNCs) locating R&D labs in developing countries such as China and India[1]. This in turn raises new challenges. Once MNCs set up R&D centers there, how do they assure retention of their intellectual property (IP)? Our research suggests that IP protection does not solely rely on exogenous institutions such as the patent system in a country. Our study finds that appropriability hazards are partly endogenous and are amenable to management. Considering the weak intellectual property rights (IPR) regimes developing countries typically have, the endogenous aspects of appropriability become more prominent for MNCs. MNCs choose to locate R&D labs in developing countries with weak IPR regimes because they have found ways to manage the risks of losing their IP, even in these weak regimes. Using evidence from MNC R&D labs in China, this study supplements the 'globalization of R&D' literature by connecting the literature on global R&D networks with the issue of managing IP. By exploring the substance of MNCs' R&D activities in China and how MNC R&D labs protect their technology there, this research proposes that IP protection and appropriation of returns can be realized through hierarchical segmentation of R&D process *within* an MNC's global network. 'Hierarchy' in this paper refers to a decomposition of a complex system into a structured ordering of successive sets of subsystems. (Sanchez and Mahoney, 1996) Modularity, a solution which enables design independence and flexibility by breaking up a complex product or process into subsystems (or modules) *(Baldwin & Clark, 1997)*, can naturally be applied to segment R&D process within an MNC in a way that protects IPR in developing countries.

[1] MNCs were already locating more than 10% of their R&D activities overseas in the 1970s and early 1980s (Mansfield, Teece and Romeo, 1979). However, these R&D activities abroad, and therefore the relevant studies, were mostly limited to developed countries. Since the mid-1980s, we see MNCs setting up R&D labs in India; and only since the late 1990s, there has been a surge of MNC R&D labs in China.

2. Theoretical background

While many studies have examined the incentives for locating R&D abroad, the literature has become unnecessarily confusing due to the use of different terminologies to characterize rather similar observations. For instance, Gassmann and von Zedtwitz (1998) classified driving factors into input-oriented, output-oriented, efficiency-oriented, political/social-culture related, and external factors (such as merger and acquisition). Reddy (2000) used market-related, technology-related, cost-related, technology monitoring, and non-R&D-related incentives. According to Bartlett and Ghoshal (1991), to exploit firm-specific capabilities in foreign environments, MNCs need to build R&D sites that are in close proximity to factories in host countries so that those R&D sites can facilitate technology transfer from the home country to the actual manufacturing. Meanwhile, other studies (Cantwell 1989; Florida 1997) show that the motivating factor for FDI in R&D might be a firm's need to augment its knowledge base, since host country R&D organizations (such as research universities) have potential knowledge spillovers. Kuemmerle (1999a) termed these two different types of incentives "home-base-exploiting" (HBE) and "home-base-augmenting" (HBA). However, in developing countries, the HBE type of incentives may be more prevalent than the HBA type.

To make greater sense out of this confusion for the empirical work that is to follow, we propose to categorize the factors discussed above into attractive local resources and host country market from supply and demand perspective. Attractive host country resources include low-cost labor, technology, local government preferential policies, presence of manufacturing base, etc.

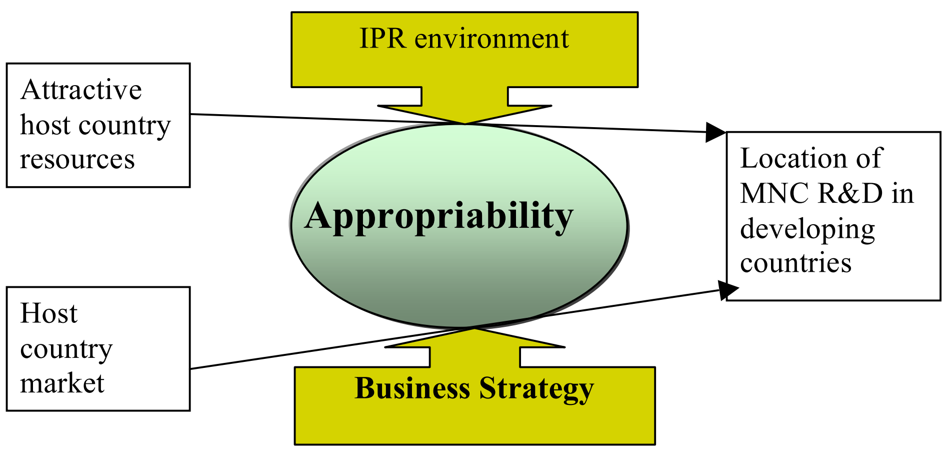
In addition to these supply and demand-based factors, a third set of considerations concern the IPR institutional environment in which R&D investments are made. Of particular interest for our study is the question of how the strength of IPR regimes may affect international technology transfer. Many studies show that stronger IPR is necessary to attract technology transfer. Empirically, an index of the strength of IPR regimes[2] is usually built as the independent variable. There are some studies, though, that do not show a direct relation between strong IPR institutions and technology transfer. For instance, Bascavusoglu and Zuniga (2005) found that stronger protection is irrelevant to the attraction of knowledge contracting to developing countries in R&D-intensive industries. Kumar's regression analysis (1996) also appeared to suggest an irrelevance between R&D investments and the level of intellectual property protection in the host developing countries, contrasting to a positive relationship between these two variables in developed economies.

This constitutes something of a puzzle that motivated our research into foreign R&D investment in China. Nowadays multinational corporations are increasingly locating R&D labs in developing countries such as China and India, which typically have weak appropriability regimes (esp. IPR). So, how do MNCs with R&D centers in developing countries protect their IP there? If no consistent empirical evidence is found between the strength of IPR regimes and international technology transfer, there must be some other ways for MNCs to protect their IP in these developing countries.

[2] Several indices were built to measure the strength of IPR regime of a country. These indices include Opacity Factor, Law & Order index, Piracy Rate, etc. For a detailed explanation of the indices, see Zhao (2006).

In our study, we find that a fourth factor, the architecture a firm uses to partition its R&D, combined with the firm's conscious policies to limit the scope of technology that it transfers, can also explain technology transfer, even in environments of weak IPR. The purpose of this paper is to address and analyze firms' strategy to manage IP for R&D conducted in weak IPR regime developing countries. Due to a lack of existing data on the behavior of MNC R&D labs in host developing countries, this research employs field study to provide first-hand data in information technology industries.

Figure 1. Why do MNCs locate R&D in developing countries?



3. Research methods and data

This research investigates MNC R&D labs in China and how R&D strategy can respond to China's weak IPR regime. Throughout the paper, we rely upon the OECD's definition of R&D, in which R&D is comprised of basic research, applied research, and product development. At a more detailed level, R&D covers a wide variety of activities from relatively minor adaptations of existing technologies or products (localization of existing products) through design activities within established architectures (development of new products) to developing new architectures (new product systems).

China's status as the world's biggest developing country and the recent surge of MNC R&D lab investments in China in recent years combine to make China an ideal location for an in-depth study on globalization of R&D. However, data on the number, growth, and nature of MNC R&D labs in China are scarce. To explore the issue, qualitative case study research[3], a small scale survey, and extensive interviews were the main research methods employed, complemented by secondary information. In fact, three object pools were used in the research to provide evidence: a smaller pool that served as the subject of case studies, a larger pool for the survey[4], and an even larger pool for the interviews. All surveys were conducted on a face-to-face basis by the first author.

In organizing our qualitative work, we were mindful that different industries have different technological and innovation characteristics, causing firms in different industries tend to have different strategic behaviors in terms of R&D. In order to make our cases more comparable, we focused on information technology (IT) industries in this research. Our selection was further encouraged by the fact that IT industries have been the industries where foreign R&D investment in China has been most active.[5] Attracted by the fast-growing market, most large IT firms have invested in China, including for example Intel, IBM, Microsoft, HP,

[3] See Yin (1989: 15-26) on the advantages of case studies.

[4] It is difficult to obtain access to foreign R&D labs in China. Also, since there is no official list of the names and contacts of foreign R&D labs, it is not feasible to do a large scale survey throughout China within reasonable time constraints. Sample data for the research are explained later. Survey by mail was tried, which, however, proved to be an unsuccessful method in China.

[5] This fact may also bring potential bias to the study. MNCs' R&D activities in other industries may behave differently from those in IT industries at the global scale.

Oracle, Cisco, Nokia, and Motorola, and many of them have set up R&D labs there. To be consistent with Chinese statistics data, IT industries here include electronic and telecommunications equipment industry and computer applications and services industry.[6]

China is itself a large and diverse country, so we also had to select regions to focus upon for field research. Beijing was selected as the major case regions in China for several reasons. First, Beijing has already attracted more than half of all the foreign R&D centers in China[7]. Second, most MNC R&D labs in Beijing are in IT industries. Third, Beijing is characterized by a dense cluster of high quality universities with which MNCs are eager to set up cooperative relationships. Interviews were also conducted in Shanghai as complementary analysis due to the reason that Shanghai is the only other city in China comparable to Beijing in terms of foreign R&D presence. As a historical industrial base, Shanghai enjoys advantages such as a mature business culture, strong government support, convenient life services, and professional labor pool. MNC R&D labs in Shanghai cover diversified industrial fields spanning chemicals, auto, life sciences, consumer electronics, and IT.

One initial issue is to identify the number of MNC R&D labs in China. The number is in fact unclear as different data sources show surprisingly diverse numbers (Figure 2). The difference in the number can partly be explained by the difference in definitions of MNC R&D labs. For sources with a large number, chances are good that those foreign companies whose R&D activities are integrated with manufacturing or services operations are included. This study only examines foreign R&D labs that are stand-alone facilities and are majority-owned affiliates

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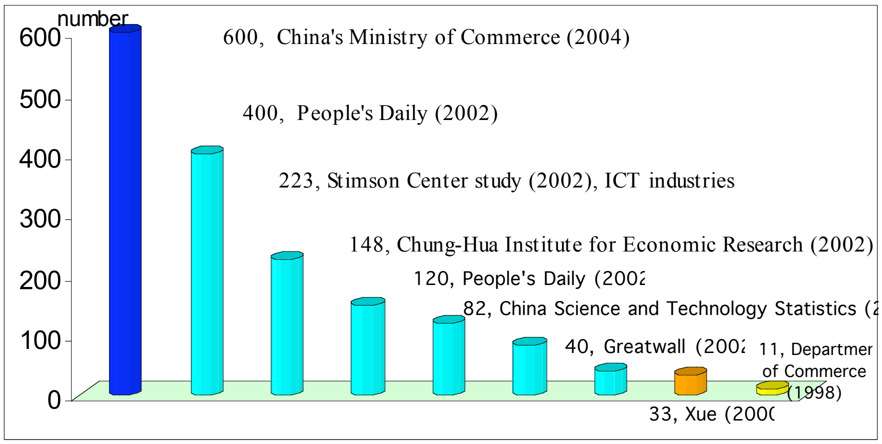
[6] The industries are mostly covered in NAICS code 334 and NAICS code 51 (North American Industry Classification, 2002).

[7] Data source: China Ministry of Science and Technology.

of foreign parent companies[8]. Data from China Science and Technology Statistics (2002) and the official R&D survey in Beijing described below more closely embody this definition.

Figure 2. Estimates of Foreign R&D Labs in China, by different sources



Various data sources: Walsh (2003, Stimson Center), China Science and Technology Statistics, People's Daily, Xue (2002), Greatwall (2002).

One of the best official data available on R&D in Beijing is the Beijing R&D Survey starting from the year 2000 (following a national R&D survey in 2000) by a joint official group including the Beijing Science and Technology Committee, Beijing Bureau of Statistics, Beijing Committee of Education, and Zhongguancun Administrative Committee of Science and Technology Park. According to the Beijing R&D Survey, there were fifteen[9] foreign R&D labs in Beijing in 2000, focusing on computer applications and services industry (6), electronic and telecommunications equipment industry (2), and industrial instruments and office machinery (2), etc. In 2002, the total number increased to twenty-five[10], with the most widespread focus remaining on IT industries (15).

[8] Majority-owned affiliates of foreign parent companies are those affiliates in which the combined ownership of home country foreign parents is more than 50 percent (Moris 2004).
[9] The number here is conservative.
[10] Again, the number here is conservative.

Clearly, data from official statistics and other public information are far from sufficient to investigate the issue. Therefore, important information is mostly gained through field study. About seventy interviews were conducted in Beijing in 2004, more than half of which involved fourteen foreign-owned R&D labs in Beijing (with most interviewees working as lab directors or other high-ranking managers of the labs). The remaining interviewees include industry experts, government officials, and university professors who collaborate with MNC R&D labs in Beijing. In addition, over 200 interviews with managers, entrepreneurs, engineers, and officials from the recent few years of research on related topics in China conducted by the first author also greatly contributed to our understanding of the issue. Among the fourteen labs we studied in Beijing, twelve were established in the year 2002 or earlier. Since there were 15 such labs identified in the 2002 official R&D survey as mentioned earlier, it means that our study covers approximately 80 percent (12 of 15) of the foreign IT R&D labs that were launched before the end of 2002 in Beijing.

4. The Nature of R&D in developing countries

Understanding the substance of MNC R&D in developing countries is necessary before we examine the appropriability issue that is the primary research focus of our paper. While it is natural for MNCs to learn the latest technologies by being located in places that are on the cutting edge of innovation (Pearce 1989, 1999; Håkanson and Nobel 1993; Florida 1997; Nobel and Birkinshaw 1998; Kuemmerle 1999b), the literature of the 1980s and 1990s suggest that MNC R&D was established in developing countries primarily for the purpose of image building, *local* adaptation, supporting *local* manufacturing subsidiaries, and, at most, product development for *local* markets (Behrman & Fischer 1980; Dunning 1994, 1998; etc.).

However, more recent literature on offshore R&D in developing economies such as Taiwan and India suggests a different pattern of development. While a close relationship with production is still observed for offshore R&D in some Asian regions (Amsden *et al* 2001; Liu and Chen, 2003), Reddy's work (2000) stated the increasing importance of a global technology unit (GTU) that performs R&D for a global market in developing Asia. Notably, our research conducted in China echoes those of Reddy's findings and some other recent studies on MNC R&D in China (von Zedtwitz 2004; Sun, von Zedtwitz, Simon, 2007).

Nature of R&D activities in MNC R&D labs in China

The result of our survey shows that product development for the *global* market is the most important function of the surveyed MNC R&D labs in China, a finding that is consistent with Reddy's notion of a GTU. On a scale of "0" to "5", where "5" represents the most important, MNC R&D labs rated "develop products for the international market" the highest (with an average of 3.9), followed by "maintain linkages with local universities and industries" (3.5) and then "develop products to be produced and sold in China" (3.0) (Figure 3). While earlier literature which found that R&D activities in the local market were largely focused on the local market, this research, however, shows that innovation for the global market is an important task for those offshore MNC R&D labs in China[11]. To better understand MNC R&D activities in host developing countries, our strategic positioning diagram (Figure 4) categorizes three positions based on MNC R&D labs' market orientations and product development strategy.

Figure 3. Functions of MNC R&D labs in China.

[11] Self-reporting from R&D lab managers can be biased. Therefore, interviews and case studies are also analyzed later to confirm the point of global market orientation.

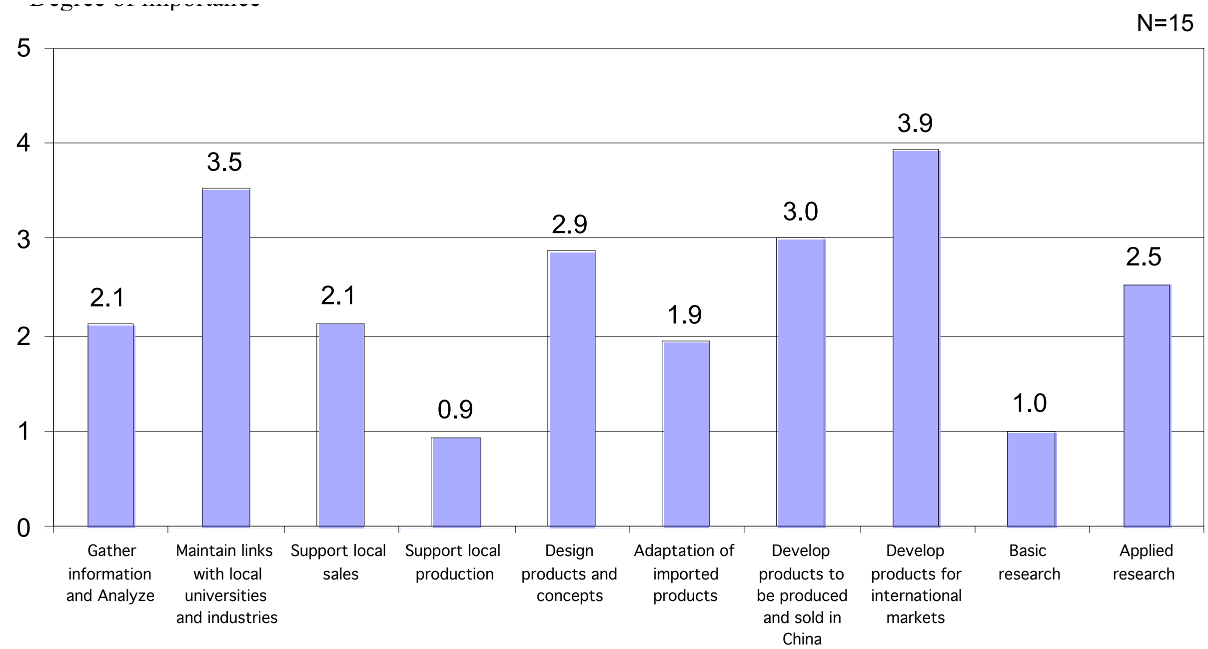


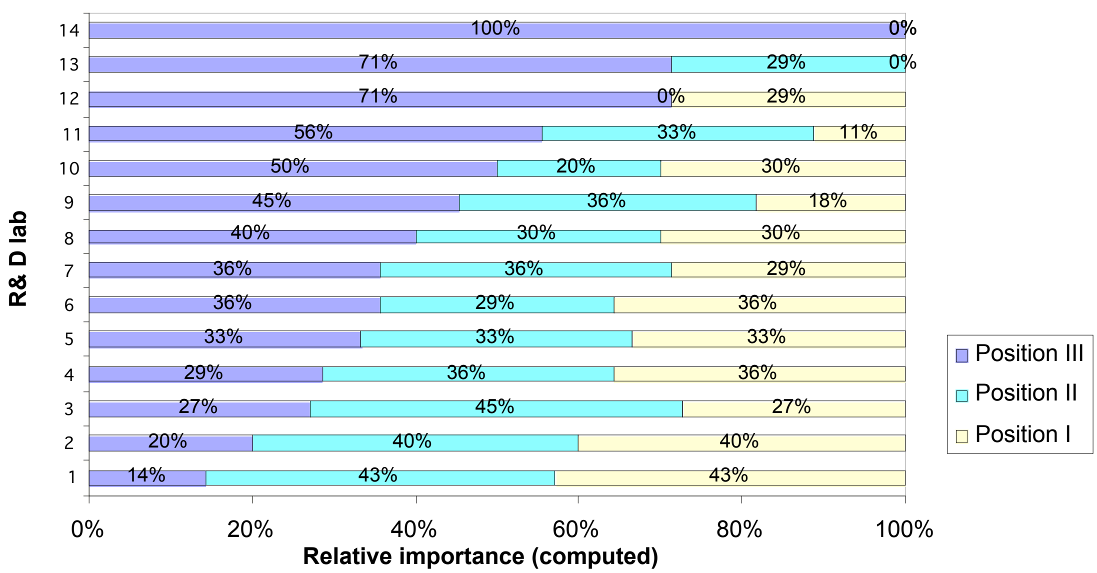
Figure 4. Positioning MNC R&D labs in MNC's spatial innovation strategy

		PRODUCT Old	**PRODUCT** New
MARKET	Global		Position III
MARKET	Local	Position I	Position II

Local market in Figure 4 means host developing country markets such as China, which are mostly new emerging markets for MNCs. At Position I, MNCs' R&D labs in developing countries focus on relatively low innovative activities such as local adaptation of imported products, technical support for local sales, and production support. At this position, no effort is put into developing new products in the emerging markets, but only product adaptation. At Position II, new product development for the emerging markets happens, which means that MNC R&D labs in host developing countries have started to identify and meet local needs. At Position III, new product development is conducted in MNC R&D branches in developing countries not only for local market needs, but also for further adoption in the 'developed country' market and/or other emerging markets. Therefore, a global market orientation can be identified at Position III. R&D labs that are targeted mostly at research (either applied research or basic research) can also be roughly classified into Position III due to the mid- to long-term research orientation, which is often applied later to global market product development. R&D labs of different MNCs have different functions in China and can be found at all three strategic positions. It is also not unusual to see one MNC R&D lab situated at all three positions. Our research shows that in some instances MNC R&D labs are likely to perform functions corresponding to those at Position I at the beginning stage upon entering the Chinese market. For example, the SAP lab in China has evolved from Position I to Position II to Position III over years of development. Nonetheless, there is not enough evidence from this research to suggest a clear evolutionary path for all labs.

To clearly depict the "positions" of the surveyed R&D labs in China, Figure 5 is drawn based on the information collected from each individual MNC R&D lab. The figure suggests that a significant part of R&D activities in those MNC labs in Beijing have a global market orientation. Moreover, the intention and fact of global market orientation are actually stronger than what the data in Figure 3 and 5 can show. As the director of an MNC R&D lab who rated the importance of three positions as equal in the survey, clearly states, "this Beijing lab is definitely not just for the Chinese market. Although supporting local business is one of the mandates, we are definitely global market oriented." Further interviews on the detailed R&D activities confirmed his statement. Interviewees from many other MNC R&D labs made similar declaration. This global market orientation of many MNC R&D labs in Beijing illustrates a new aspect of MNCs' global innovation strategies, and is different from many earlier studies that believed or assumed that local adaptation is the major function of R&D in developing countries, as discussed earlier.

Figure 5. Positioning MNC R&D labs.



Note: 1) One R&D center which completely focuses on research is not shown in the chart. 2) The percent value is calculated in a way to reflect the relevant importance of R&D activities corresponding to different positions for a certain R&D lab. For example, if a lab gave same score for importance of R&D activities in all three positions, the percent value is shown as 33%, 33%, and 33%.

Although a global market orientation does not necessarily indicate high value-added R&D activities in host developing countries, to do innovation for the global market, MNCs must transfer significant know-how to China, which makes MNCs face a high risk of losing their competitive advantages. As Mansfield *et al.* (1979) put it, if the nature of R&D conducted overseas is focused on "the modification and adaptation of products and processes for the local market, there is less need to transfer much of the firm's most sophisticated technology overseas than if the work is focused on major product or process developments intended for a worldwide market." With a global market orientation, when IPR can be well protected, MNCs are able to explore global resources to a larger degree while still appropriating from those global R&D activities. On the other hand, when IPR regime is weak in host countries, MNCs need to seek for other solutions to compensate for the weak IPR institutional environment. According to our research, hierarchical segmentation of R&D process within an MNC's global network is such a solution. By specifying interface protocols, MNCs in the information technology industry can use modular structure to well control and manage the types of know-how transferred to developing countries, therefore lowering the risks of losing their competitive advantages.

5. Hierarchical segmentation of the R&D process *within* an MNC

Firms' production activity and R&D activity have long been separated spatially, displaying specialization based on resources from different organizations in different locations worldwide. However, specialization in R&D activity within organizations still needs to be studied. R&D activity has its own value chain and different actors can specialize in different R&D segments along the chain.

How are R&D activities organized within a firm? How does this relate to whether firms will locate R&D activities in regions with weak IPR protections? A relevant recent study conducted by Zhao (2006) argues that in weak IPR regime countries MNCs tend to cite more patents from within the organization such as home country branches, thus a close internal organizational structure in the sense of technological development can be observed as a means of IP protection for MNCs in developing countries. Our research agrees with Zhao's finding. However, on the other hand, Zhao's analysis is limited by the regression methodology [12] on patent citation, which, though providing statistically significant results, lacks the power to 'open up the black box' of the R&D organization. The patent citation data are not sufficient to reveal what exactly a close internal organizational structure means, which actually requires in-depth field work. Our research thus complements Zhao's findings, and goes further by investigating the precise R&D organizational structure of MNCs. A key proposition in this study is that **an MNC can hierarchically decompose the systems that draw from the R&D process within its global R&D network to protect intellectual property in weak IPR regime developing countries**. Particularly, **a modular R&D structure can be used to facilitate such segmentation.**

This echoes the argument in Levin *et al* (1987) that formal IP institutions are not indispensable for returns appropriation in many industries (including IT). As they observe, patents are effective in only a few industries such as chemical industries, while other mechanisms, such as lead time, learning curve advantage, secrecy, and sales and service efforts, are better means of appropriation in some other industries. Our study extends the discussion by identifying the strategy of R&D process segmentation as an effective means of IP protection in the context of globalization of R&D.

[12] See Gummesson (2000) for more discussions on limitations.

6. Case Studies

In this paper, we present three case studies to illustrate how R&D processes are hierarchically segmented within each MNC based on a modular R&D structure and how IP is protected accordingly. The true names of the companies are not disclosed. All analysis is based on the field survey and interviews in China.

MNC A: Software development is typically modular. MNC Lab A in Beijing is wholly owned by MNC A, a global leader in providing collaborative business solutions (or, ERP software) for all industries. The lab was officially launched in November 2003 in Beijing[13], but its R&D activities in China have started since 1993. In the early years after its entrance (1993-1997), the major focus was on localization of the company's existing products for the Chinese market. In 1998, the lab began project based development for local market and started to build its own credibility.

Now almost all R&D work (99% in terms of investment) in the lab in Beijing is on product development. The lab engages in enterprise solutions that focus on small and mid-size businesses, Linux solutions, supply chain management, and manufacturing-related solutions. There were around 130 employees in the China labs (including both labs in Beijing and Shanghai) at the time when the initial field work for this research was conducted in 2004. It increased to 400 employees by the end of 2005 and has a target of around 1,500 in 2009, according to the first author's second-round interview with one key product development director of the lab in early 2006. About 30 percent of the employees hold a Master's or PhD degree. MNC Lab A has

[13] One lab was established in Shanghai at about the same time.

developed into one of the eight largest labs of this MNC and is one of its fastest growing subsidiaries.

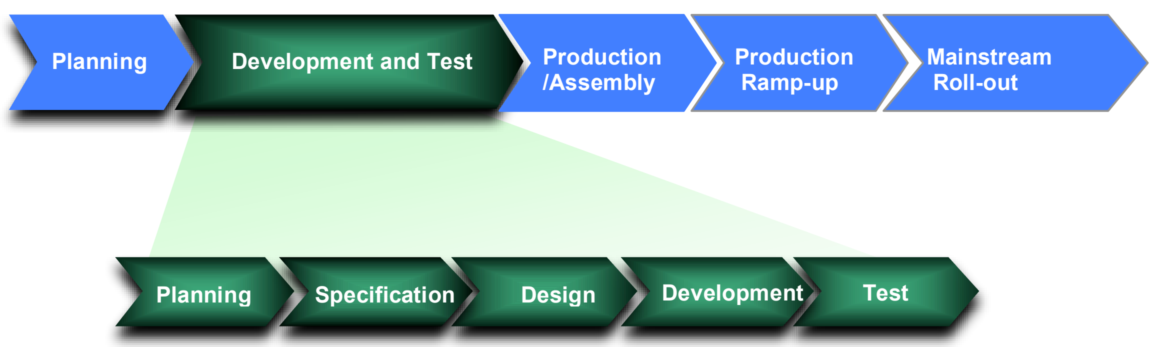
MNC Lab A now is part of MNC A's global development network. The major market orientation of this lab is global market and Asian market. One lab manager in the survey considered 'design products and concepts' for 'global markets' as the most important function of the China lab. Further interviews revealed the substance of these R&D activities. An evolutionary path can actually be observed in the MNC Lab A case. When MNC A began some development projects in China in 1993, the focus was localization and translation of existing products (corresponding to Position I in Figure 4). From 1998, cooperation with the firm's headquarter was seen for product development for the local market. In 2002, MNC A launched a development center there (not yet a 'lab'), which still focused on the local market (Position II in Figure 4) and was not integrated into the global market. Because the development center was successful, in November 2003, MNC A formally announced the establishment of its R&D lab in China, which started to actively involve in the company's global- or Asian- market oriented product development (Position III in Figure 4). Now with R&D abroad in Bulgaria, China, India, Israel, Japan, and North America, MNC A's labs form its global R&D network to integrate ideas and technologies that address the needs of specific industries and geographic regions. "Our company follows a distributed (or decentralized) development strategy", says the Vice President of Operations of MNC Lab A in China. (interview) About 30% of its R&D is globally distributed, that is, outside of MNC A's headquarter labs.

R&D activities in this China lab of MNC A illustrate our statement on hierarchical segmentation of R&D process. Usually product development in the lab does not start from scratch. For instance, the first R&D project that the lab did was on decoupling of the Human Resource (HR) Module from the firm's existing product solutions, responding to the increasing trend of HR function outsourcing from local companies in 1997 and 1998. For that project, the major HR components were already in existence. It needed a way to separate the HR module from the system, and all the R&D personnel in Beijing then (about 20 people) focused on the project. The core of the product, the architecture design of the overall solutions, is deemed essential to the MNC's competitive advantage and therefore placed in the headquarter lab. The critical part of the decoupling work, which involved revealing some architecture information, was located in the home country as well. Some R&D personnel in Beijing were then sent to the headquarter lab for the decoupling job and further training, while transferring a small amount of technology information back to China. Most functions of the module in the global version were kept in the local version. Since the Chinese accounting system is different from other countries, limited local specific functions were developed into the local module.

In this case the hierarchical segmentation of R&D tasks was probably only partly caused by IP concerns. An equally important concern appeared to be the perceived low level of local R&D capability. However, as the capability of the local lab became stronger (and was demonstrated to the headquarters to be stronger), the capability concerns receded. Now the appropriability issue is becoming a major concern for the MNC. As expressed by the lab manager, the weak IPR regime in China is indeed a great worry for the firm. As a result, new knowledge that would be commercially valuable and easy to replicate is not produced in China.

To protect its IPR, the MNC has implemented a thorough hierarchical compartmentalization of its R&D. As we see in the product development process of the company's one major current product (Figure 6), production assembly, which puts all components developed throughout the world together into a solution at the R&D stage, is done in the headquarter lab based on architecture knowledge. "All the CDs and related work at the R&D stage are also printed in home country". (Interview) Currently, in China, the major R&D work is at the phase of *development and test*, which involves more detailed planning, specification, design, development, and testing. With this center-peripheral spatial configuration strategy, R&D tasks in China deal with modules following the design requirement from the planning stage, which is overall system architecture design done outside of China.

Figure 6. Development process of one solution product of MNC A.



Overall, we see that the company configures its R&D resources globally based on hierarchical segmentation of R&D processes, with its labs in different locations focusing on different development tasks. Usually its labs in the US and in Japan serve as market listening posts to understand the needs of its most demanding customers. Labs in China and India are established mainly for the rich local R&D labor pool, with low level of design information transferred to these developing countries as IP is concerned. Indeed, labs in different places collaborate on development projects. "They create different parts for the same product, and share knowledge. For each business solution project, it can combine different development teams from different labs in the world." (Interview) Architecture designs, core R&D to the firm, are always located in its home country R&D lab, serving the entire global market.

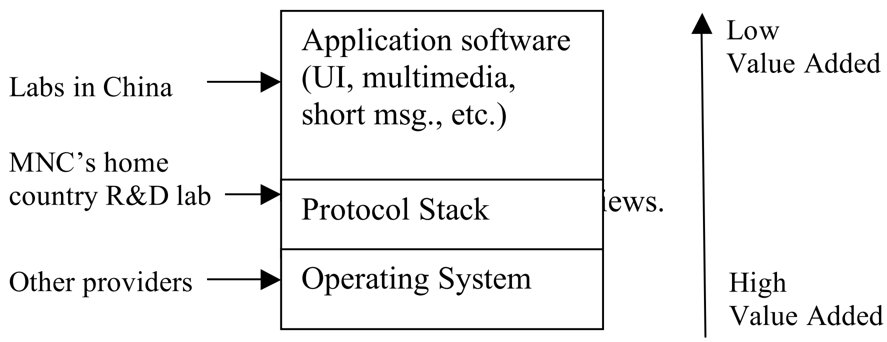
MNC B and MNC C: MNC Lab B and MNC Lab C are wholly owned by MNC B and MNC C respectively, which both are among the world's largest semiconductor companies. Although chip design is the major source of profit for the two semiconductor firms, R&D work in chip design is shown in none of the labs in China.

MNC Lab B locates in Shanghai, and has been in presence for over two years by the time of the first author's interviews in 2005. With about 50 engineers in Shanghai, the lab focuses on software development for mobile phones, a major end use of the chips being developed. R&D activities in the lab also focus on the Asian and global market. Product development is the sole activity in the lab, while no early stage research work is conducted.

Similar to MNC A, MNC B also has a distributed global R&D network, with many lab locations in North America, Europe, and Asia. Hierarchical segmentation of R&D processes can be observed as well between its Shanghai lab on the one hand, and the labs in its home country and other developed countries on the other. Our interviews revealed that engineers in the Shanghai lab take key components available from MNC B's other branches and components purchased from the market to do integration work for customers in China. The R&D activity in China basically is low technological value-added, while core R&D is located outside. As the

Lab Director put it, "In order to develop application software for mobile phones, we need to get OS (operating system) licensed from other providers and get the protocol stack from R&D branches in our headquarter R&D" (Figure 7) (Interview). Here, the protocol stack conveys architecture knowledge with high technological value and is placed in the MNC's home country R&D lab. Application software that are developed in Shanghai, including user interface, multimedia software, short messaging, etc., lie on top of the protocol stack. This illustrates that MNC B's R&D activities in China are low value-added in its hierarchical R&D chain.

Figure 7. Resource spatial configuration strategy based on hierarchical segmentation of R&D process, MNC B.



A vivid example given by the Lab Director further demonstrates how the concern of IP issue influences the lab's R&D activities. "In China, IP protection is indeed a problem. Our one case of IP infringement was discovered accidentally. We noticed that one software product we delivered to our customers in China was 'opened up' and even discussed in detail on the Internet. Chinese customers do not know that the IP in the software still belongs to our company. Later, we sent a lawyer to the customer and required that the website be shut down. This IP infringement was only found out by us accidentally. It can be imagined that more of this kind of IP infringement is happening in China. Although software developed in this lab is for our own products specifically, competitors can still steal the software architecture or some specific module of the software products [for their own products]. This can be a potential risk for us." (Interview) As a result, the company decides that only very few software engineers in the Shanghai lab can have access to the knowledge of the whole software system. Most R&D engineers in the lab there focus on detailed modular work within the application software themselves.

MNC Lab C, one of the US-headquartered MNC C's biggest overseas research labs, was established in Beijing in 1998. It was the first lab of MNC C launched in Asia and it had about 70 employees in Beijing in 2004. As a research lab, more than 90% of the employees there hold a Master's or PhD degree. The lab however is not solely research focused. Further interviews with the lab director show that about 40% of the R&D projects in the lab focus on product development, while the remaining 60% on applied research. No basic research is conducted in this lab.

The lab director emphases that the Beijing lab is oriented towards the global market, and is closely integrated into the company's global R&D network—Corporate Technology Group (CTG). Worldwide, MNC C has about ten labs belonging to this group, with locations in China, Russia, India, Korea, Spain, England, and the headquarters in the US (with several R&D labs there). About 40% of the company's technology comes from its labs worldwide. According to the interview, this does not mean that the company is developing different products in different locations, but that it follows a hierarchically segmented R&D structure. "Our company doesn't have China-specific products, only chips that can be used worldwide" (Interview). Production or technology development is conducted in locations where it is believed to be most appropriate considering situations such as local talents and markets. As a rule, the headquarters define the architecture, and then give some detailed tasks to R&D labs in different locations. After the designated tasks are completed in each location, the technology developed there is then transferred back to CTG and then to production groups, which can be located anywhere needed. In China, MNC C also has a product development center in Shanghai with a focus on software, and a development center in Shenzhen on wireless technology. The Beijing lab focuses more on applied research. As a result, close collaborations are mostly found with MNC C's R&D labs outside of China.

Wireless technology development in a broad sense can be used as an illustration for the global R&D cooperation in MNC C. Generally speaking, "integrated circuit (IC) design is done in the US, algorithms are developed in Russia, and platform is done in China. Although the development of platform also requires high technology, it is not core technology. Core technology is developed in the US with its IP well protected", according to the lab director. Platform development usually sits on top of core components developed in the headquarter labs, with specified interface parameters. In the case of the semiconductor industry, government policy may also influence the types of R&D activities done in China; however, high-tech export control from the US government is in fact also due to a concern of losing key IP and technologies to the Chinese competitors. If the government factor is left aside, allocation of R&D resources globally in an IP-favoring way is still mainly corporate decision. As we can see, core technologies of earlier generations, which are not on the list of the US government export restrictions, are not conducted in the labs in China as well. Protection of intellectual property rights is indeed a major concern for the company and hierarchical segmentation of R&D is one method of technology protection.

7. Interpretation of Case Studies

To understand how a modular structure can help compartmentalize the R&D process, we first examine the concept of modularity. Modularity refers to the ability to partition complex systems into smaller subsystems (modules) with clearly defined interfaces (e.g., standards or design rules) that enable the modules to interoperate (Baldwin and Clark, 2000).

With different organizational boundaries, modularity can be applied either within a firm or among different firms. Modular production among different firms has been studied at the industrial organization level (Sturgeon 2002; Lester 2003, etc.). Discussion on modular design among different organizations has focused on the boundary between internal R&D and external R&D, be it among firms (Brusoni 2001; Ernst 2003; Chesbrough, 2003), or between firms and other institutions such as universities or government funded research institutes (Mowery 1995; Chesbrough 2003). Within a firm, production taken place in many different locations has long been observed. For example, cars can be assembled with parts coming from different locations. But the issue on modular R&D within an MNC has not been clearly put forward and this is what this research contributes. A closely related body of literature on the globalization of R&D has, however, not dealt with the concept of modularity. By linking the protection of intellectual property to the choice of MNC R&D lab activities, we are able to bring these concepts together.

Figure 8. Dimensions of modularity

Organizational Boundary

	Production	R&D
Among firms	Modular production among firms Sturgeon (2002) Lester (2003) Etc.	External vs. in-house R&D; modular design among firms Mowery, Brusoni, Baldwin & Clark, Ernst, Sanchez & Mahoney, Chesbrough, etc.
Within a firm	Modular production within MNC Flexible manufacturing system; e.g. auto manufacturing	Modular R&D within MNC (focus of this study)

Functional dimension

Figure 8 provides a two-dimensional classification of some typical arguments from previous modularity literature, and positions this research in the diagram. The two dimensions of modularity in the diagram are “functional” and “organizational.” The functional dimension here differentiates the production function and the R&D function.

The exact structure of modularity varies a lot across different products. Even for the same product, companies can decide on the type of architecture that they want to adopt as long as no strict industrial standard is involved although they may follow the dominant design paradigm. Despite of limits to modularity (Sabel & Zeitlin, 2004; Chesbrough 2004), it is unquestionable that modular architecture is a common structure within IT firms since it can have the benefits of “effectively limiting complexity and providing for future flexibility and change” (Messerschmitt 2000), even though not all R&D projects follow such an architecture. In fact, most IT firms interviewed in this study have adopted modular structure for their R&D activities.

Segmentation Through System Decomposition—Center-Peripheral R&D structure

The hierarchical segmentation of R&D process facilitates a center-peripheral R&D organizational structure within an MNC, making the location of R&D in developing countries desirable. Generally speaking, the organization of MNC R&D can be centralized, decentralized, or a hybrid structure[14] (Bartlett & Ghoshal, 1991; Archibugi & Michie, 1995; Zander, 1999). Whereas decentralization can help expand markets to emerging economies, centralization is usually efficient for internally focused systems to create markets with breakthrough innovations (Tirpak, Miller, Schwartz, & Kashdan, 2006). The choice of R&D organizational structure depends on the firm's corporate culture, its manufacturing and marketing structure, and preferences of the CEO (Larson, 2007). Decentralized R&D organizational structure became common in the 1980s, and was further propelled by the growing trend of globalization since the 1990s. The segmentation of R&D process in our research also illustrates a decentralized R&D organizational structure. A center-peripheral spatial arrangement of MNC R&D activities in this structure is identified as MNCs' organizational response to the weak IPR protection environment in China.

To better understand the hierarchical center-peripheral R&D structure, another two-dimension diagram is drawn (Figure 9). The spatial configuration of R&D activities is determined by both the value of the R&D activities and appropriability of the value. Appropriability, determined by technological attributes and the strength of IPR regimes, signifies the efforts MNCs have to make in order to gain profits from the R&D activities they engage in. According to Teece (2000), appropriability is a function both of the ease of replication and the

[14] For example, large companies with multiple business units may have a hybrid R&D structure.

efficacy of intellectual property rights as a barrier to imitation. "Appropriability is strong when a technology is both inherently difficult to replicate and the intellectual property system provides legal barriers to imitation. When the technology is inherently easy to replicate and intellectual property protection is either unavailable or ineffectual, the appopriability is weak" (2000:19). To separate IPR institutional environment which is external to firms and is not amenable to management, "protectability" is used to specifically describe the ease of replication from the technological perspective.

Figure 9. Locations of R&D activities based on value-added and protectability

Protectability \ Technological Value-added	High	Low
Low	Developed Countries	
High		Developing Countries

As shown in the diagram, when the technological value-added of a particular R&D task is high (typical 'core' R&D) but protectability is low, MNCs prefer to locate the R&D task in home countries or other developed countries that offer strong IP protection; when the value-added is low (typical 'peripheral R&D') but protectability is high, the location preference is in developing countries for reasons such as low cost.

This has important implications for IP and appropriability. Usually, the more that design information is revealed by certain R&D activities, the easier it is for outsiders to replicate, which puts MNC R&D investment at great risk. But systems decomposition in a modular design structure can segment design information into three levels: architecture level (which defines how to divide the overall functionality into a set of sub- or partial- functions that make up the whole); interface level (which describes how different modules will interact or what services each module will provide the others); and module protocols (which deals with how a specific module will work) (Baldwin & Clark 2000). This suggests that MNCs might wish to approach these different levels of information differently when making choices on R&D activities. And that is what we see in the three case studies. The system level knowledge, i.e., architecture level, usually conveys all the important information and has the highest technological value since it decides what the overall system will look like. The value of this knowledge is the highest of the three. The ability to appropriate gains from R&D is damaged the most if this knowledge is lost. As a result, the related R&D activities usually carried out in the headquarter R&D lab. The interface level protocols are also normally designed in the headquarter R&D lab for the knowledge it requires to enable and embody the systems architecture. While the specifications can then be shared across different R&D branches for further design and development, the creation of the interfaces needs to remain close to home as well. The component modules, by contrast, contain extensive information about the modules, but rely on the interfaces to connect back to the systems. The local R&D center will know the "what" from the module specifications, but it may not perceive the "why" or the "how". (Garud, 1997) Therefore, generally speaking, in a modular structure, 'core R&D' may include architecture design, interface protocol, and some R&D for the most highly valued components. Such core R&D usually embodies crucial knowledge that if leaked or disclosed, could enable others to replicate the technology with no payment directly to the company. Due to the weak IPR regimes developing countries typically have, the strategy for MNCs is to locate core R&D in their home countries or other developed countries.

However, if the R&D work itself is not easy to imitate, i.e. protectability is high, or it is not very useful to imitate the idea for any product development in competition, an MNC will not be very reluctant to place the work in a developing country. Many modules do not seem to be significantly beneficial to imitators because the functions of the modules in the whole system are not made very clear to them. To design these modules abroad, only a small amount of information, mostly interface parameters, needs to be transferred. R&D engineers working on the modules will be informed of these interface parameters, whereas they have no idea of the overall system architecture. With "hidden information" from the system, modules themselves do not convey any system information. However, there is usually still enough room for innovation in a module, as long as the interface rules are conformed. R&D lab workers in developing countries mostly engage in development of low technology value-added peripheral modules, which can be illustrated from the cases discussed above.

The upper right and the lower left quadrants in the diagram (Figure 9) are trade-off zones. For example, if protectability is low, the corresponding R&D modules are more likely to be placed in developed countries even when the technological value-added is not high. The MNC A case illustrates this point, where low technological value-added activities such as software copy and printing at the R&D stage are placed in the home country. On the other hand, if protectability is high, the decision of the R&D activities' location will be largely determined by the pools of knowledge available. Therefore, there is still a good chance for MNCs to put the corresponding R&D in developing countries despite the high technological value-added.

Modular structure is not the only way for hierarchical segmentation of R&D processes. In fact, modularity is often applied to development for one specific product. Hierarchical segmentation can also be reflected in research in a broad sense. Indeed, research is less likely or less useful to be imitated than development, although it can have strategic value for MNCs. It usually targets a firm's long-term competence (basic research such as Microsoft Research) or mid-term competence (applied research, such as Nortel's R&D lab in Beijing), without direct market application. According to field interviews, MNCs tend to place firms' core competence related strategic research in their home developed countries, but relatively peripheral tactical research in developing countries. The desire to protect the IP of peripheral research is not strong since very little information revealed to the developing countries is deemed as useful to imitators. As a result, depending also on the richness of the R&D labor pool, some research work is likely to be placed in developing countries like China with weak IPR regimes. If protectability is high, we would expect research work to be performed where there are high quality pools of talent.

Data based on the first author's field work show that the majority of MNCs' R&D activities in China involve in product development. Only a few of the MNC R&D labs such as Bell labs in Beijing focus on applied research, and Microsoft and IBM are examples that conduct basic research in China. For instance, the Microsoft Research Asia lab in Beijing focuses on theoretical research, with some efforts to help transfer technology into Microsoft products (Quan, 2005).

8. Conclusion

This study has all the usual limitations of qualitative research. While we have interviewed a large majority of MNC labs in Beijing and Shanghai, we do not claim to have a representative sample of MNC labs in all of China, let alone the rest of the world. We interviewed one or a small number of respondents at each lab, so there may be other views within those labs that we did not hear. Our work was done in 2004 and again in 2005 and 2006, in an environment that is changing rapidly. While our findings are consistent with those of Zhao (2006), more research is needed to examine these issues and see if these results are confirmed.

Though we must regard them as tentative, our results nonetheless have important implications for the literature on the emerging global R&D networks found in many industries. They also bear on the ability of developing countries to lure MNC labs into their countries. And most importantly, they provide insight for MNC managers who must construct and manage innovation activities in an increasingly distributed, increasingly global marketplace for innovation and technology.

The appropriability regime that a firm faces influences its ability to profit from innovation (Teece, 1986). IPRs are an important part of this appropriability regime. Our work suggests, though, that appropriability – the ability to capture a portion of the returns from one's investments in innovation – is more than this. Firms can structure themselves to reduce the portion of their innovation investments that are exposed to unwanted imitation. This means that appropriability is partly endogenous; therefore management strategy is important for IP protection. The appropriate strategic decision on the location of core R&D and peripheral R&D, along with a careful partition of R&D into modular parts, can help MNCs effectively appropriate returns on R&D investment. This enables MNCs to invest in labs even in weak IPR regime developing countries, while utilizing in turn the abundant local resources for innovation for the global market. Indeed, this hierarchical segmentation of R&D across geographical boundaries within an MNC to some degree makes the protection of IPR in developing countries easier.

A modular structure can lower the risk of losing IP through careful control of the know-how transferred. Besides methods such as training employees to bring awareness of IP and using IT tools to monitor and grant access to different development environments, "the product architecture and division of responsibility become a natural defense". (Interview with the director of Nortel Lab in China) As Leonard Liu, Chairman & CEO of Augmentum (a US-headquartered software firm with R&D in China), indicated, "Piracy issue is seldom solved by any legal system. We don't worry about piracy issues in China. For complex software system products, it is very hard to steal. Stealing only a piece of the product is not useful."[15]

There are implications of this qualitative work for policy as well. Many governments in developing countries wish to upgrade the jobs provided by MNC investment in their countries. Maintaining weak IPRs in the developing country may not prevent MNC investment in the country. However, if our research findings are confirmed by other studies, these findings would suggest that weak IPRs impose a more subtle limitation. They may limit the degree of value-added work undertaken by MNCs in the local country. This may retard the development of systems and architectural knowledge in the local country, which in turn might slow down the

[15] Source: Personal discussion and seminar held at SPRIE (Stanford Project on Regions of Innovation and Entrepreneurship), Stanford University.

ability of the country to catch up to the knowledge frontier in leading industries. A more hopeful finding from our work is that local R&D centers evolve their capabilities over time, so that as they become perceived by the MNC headquarters as more capable, they are given more value-added work to perform. The combination of more capable labs and modular-based restrictions on value-added may give rise to an indigenous force within the local country to lobby for the stronger protection of IPRs, in order to continue to upgrade the skills and capabilities of the local technology sector in the country.

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