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Abstract

Based on case studies of multinational R&D centres in China, this paper views the central task of corporate R&D globalisation as: differentiating R&D units to take advantage of location-specific resources and integrating R&D efforts in multiple locations to achieve the whole corporations goals. Four differentiated R&D units are identified: the technology competence unit, the system competence unit, the assignment unit, and the support unit. These four units form a complete R&D system covering all stages of R&D life circle. Three main driving resources – technology strength, human capital, and the market – are investigated, as well as their relationships to different types of R&D. Control, communication, and external collaboration issues are also discussed for these four types of R&D units.

Keywords: multinational R&D; differentiation; integration; resource; global R&D network; R&D globalisation; MNC; China

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1 Introduction

Research and development (R&D) foreign direct investments (FDI) have been growing remarkably since the 1980s: initially within the triad nations, that is, the United States, European Union member countries, and Japan (Archibugi and Iammarino, 2002; Cantwell, 1995; Patel and Pavitt, 2000), and subsequently expanding to developing countries (OECD, 2008; UNCTAD, 2005). In addition, China is one of the most significant recipients of R&D FDI among developing countries and is viewed as the most attractive destination of R&D FDI (OECD, 2008; Thursby and Thursby, 2006; UNCTAD, 2005). More importantly, scholars have witnessed that the strategic importance of R&D in foreign locations is rising for multinational corporations (MNCs). Overseas R&D was once dominated by adapting mature technology developed in the home country to better serve local market and production (Mansfield et al., 1979; Ronstadt, 1977; Teece, 1976). However, overseas R&D is playing an increasingly important role in creating new knowledge from the host country and augmenting the knowledge base of the corporation (Almeida and Phene, 2004; Cantwell, 1992; Florida, 1997; Kuemmerle, 1999a; 1999b). This transition in overseas R&D has also been observed in China (Schwaag-Serger, 2009; von Zedtwitz et al., 2007; Xue and Liang, 2008).

Given the rising volume and strategic importance of overseas R&D, many scholars have devoted to studying the nature of overseas R&D (Kuemmerle, 1997; Pearce, 1989; Ronstadt, 1977), as well as corresponding motivations behind the scenes (Florida, 1997; Hakanson and Nobel, 1993; Teece, 1976) and issues pertaining to managing R&D in foreign sites or organizing the global R&D networks as a whole (Gassmann and von Zedtwitz, 1998; Ghoshal et al., 1994; Gupta and Govindarajan, 1991). One influential study pertaining to the nature of overseas R&D is Kuemmerles (1997) dualistic classification: home-base-augmenting (HBA) and home-base-exploiting (HBE). The former takes advantage of local science and technology strengths for creating new knowledge and augmenting the knowledge base at home, whereas the latter adapts existing knowledge within the firm for supporting local special demand. These two types of overseas R&D are driven by different location-specific advantages (i.e., HBA is driven by science and technology strengths, and HBE the market and production demand) and have different managerial status (HBA has higher prestige and autonomy than HBE) (Kuemmerle, 1997; 1999a; Le Bas and Sierra, 2002). The key distinction between HBA and HBE is about the direction of knowledge flow between the headquarters at home and overseas R&D centres. In addition, in some taxonomies of overseas R&D, scholars also included the dimension of geographical area that the R&D centre serves to and suggested that global centres are of higher status than local centres (Chiesa, 2000; Nobel and Birkinshaw, 1998; Ronstadt, 1977).

The early theories of multinational R&D were developed primarily based on realities within the triad nations, because the early wave of R&D internationalization occurred primarily within the triad. Many studies of overseas R&D in developing countries found some different drivers and rationales, for example, the availability of low-cost and capable personnel (Xue and Liang, 2008). Many studies followed the tradition of previous multinational R&D (within the triad) literature and added new insights into the understanding of overseas R&D in the developing world (Gassmann and Han, 2004; Lu and
However, many other scholars interested in overseas R&D in the developing world adopted a different perspective, that is, the offshore manufacturing perspective. These scholars viewed overseas R&D in the developing world as an expansion of offshore manufacturing and relied heavily upon theoretical foundations such as modularity and outsourcing (Engardio and Einhorn, 2005; Ernst, 2005; Ernst and Kim, 2002; Lewin et al., 2009). International division of labour has extended to more innovative activities, and part of the R&D can also be separated from the value chain to be outsourced or offshore insourced. From this offshore manufacturing perspective, overseas R&D in developing countries is primarily driven by local cost-related advantages and uses low-cost human resources as accessorial workforces to serve the home country or the global market (Chen, 2004; Kumar and Aggarwal, 2005; Lewin et al., 2009). Correspondingly, this type of R&D is of low strategic importance, peripheral, and relatively routinized. For this type of R&D, Lewin et al (2009) proposed a new term, home-base-replacing (HBR), in addition to Kummerle’s HBA and HBE.

Different from the offshore manufacturing perspective, the recent reverse innovation literature demonstrated a more promising story of overseas R&D in developing countries. Reverse innovation refers to the phenomenon that original innovation emerges from developing countries and then spreads to the developed world, including the home country of the MNCs (Brown and Hagel, 2005; Govindarajan and Ramamurti, 2011; Immelt et al., 2009). Creating new knowledge from the host country and transferring the knowledge back to the home country is not new, for example, HBA. What’s new about this reverse innovation phenomenon pertains to the facts that (1) new knowledge is created from developing (lagging in science and technology strengths) instead of developed countries (with more advanced technology than the home country), and (2) these innovations are not driven by technology strength but by special local market conditions.

More recently, Wang et al (2012) argued that R&D internationalization has become more entrenched than acknowledged in previous literature that assumes the existence of a home base and views overseas R&D as extensions of home based. They proposed host-country-based R&D as oppose to home-country-based R&D (i.e., HBA, HBE, and HBR) and emphasized that the multinational R&D network has evolved from a single- into a multiple-based network with internationalized bases.

All these studies add values to the understanding of diverse overseas R&D activities in developed and developing countries. In summary, the multinational R&D perspective provides a relatively more systematic view of overseas R&D in both developing and developed countries, the offshore manufacturing perspective adds in special characteristics of overseas R&D in developing countries, and the reverse innovation and host-country-based R&D theses focus on new developments in developing countries. However, these studies are not well synthesized to provide a more comprehensive and complete framework for multinational R&D, and empirical studies following one perspective without consulting the others can result in misleading and confusing conclusions. For example, when applying the HBA/HBE framework to explain overseas R&D in China, three main issues emerge. First, in theory, HBA R&D is driven by scientific strengths and has intense interactions with external innovators in order to absorb external knowledge. In reality, however, many knowledge augmenting R&D centres in China complain about the insuffi-
icient supply of high-level researcher, and they barely have any interactions with the local community. Second, in theory, global centres are of higher status. In reality, however, many famous R&D centres advertise their “in China, for China” (i.e., local) orientation rather than a global orientation. Third, in theory, demand-oriented factors are important for HBE R&D. In reality, however, many prestigious and innovative R&D centres emphasize the importance of market. The first and second dilemmas reflect the alternative offshore manufacturing perspective. Although HBR R&D in developing countries also creates new knowledge for the firm, it is driven by low-cost labour, strictly controlled by its head offices, and isolated from external innovation networks. Furthermore, this type of R&D is global-oriented but of low strategic importance. In addition, the reverse innovation and host-country-based R&D theses may help to explain the first, third, and partly the second dilemmas, that is, the market drives not only adaptive R&D but also original innovation, and the market-pull model of innovation complements the technology-push model implicitly assumed in previous multinational R&D literature.

In summary, simply applying the HBA/HBE classification to qualify and quantify overseas R&D in China would result in misleading messages. Therefore, this study is motivated by a simple question: what is the nature of overseas R&D in China and what are the general genres of overseas R&D in China. Furthermore, the answer to this question is closely tied to two other questions pertaining to (1) corresponding motives behind given types of overseas R&D (i.e., why multinationals conduct these types of R&D in China) and (2) organizational and managerial characteristics associated with given types of overseas R&D (i.e., how the technological differentiation is reflected at the organizational and managerial dimensions. We conduct case studies to answer these questions, and what we learned from our field work can be summarised as: the logic of R&D globalisation is about differentiating R&D centres to take advantage of location-specific resources and integrating R&D efforts in multiple locations to achieve the overall corporate goals.

The rest of this paper is organized as follows. Current status of multinational R&D in China is reviewed in the next section, providing some basic information about the research setting before entering the field. Then, the research design is presented. Results of our field work are reported in three sections: differentiation, resources, and integration. The “differentiation” section reports general genres of overseas R&D in China, the “resources” section discusses the corresponding motivations (i.e., location-specific resources) driving these different types of R&D, and the “integration” section address the question of how these different types of overseas R&D centres are controlled and coordinated differently. Case studies take a highly iterative process between theory and data, in which “researchers constantly compare theory and data — iterating toward a theory which closely fits the data” (Eisenhardt, 1989, p. 541). In this iterative process, we constantly search for other literature to help make sense of the data and incorporate relevant literature into the theory building. These three sections present our final understanding but not the iterative process itself. Therefore, in each of these three sections, we (1) provide a brief review of previous literature specifically pertaining to the topic, (2) bring in insights from other relevant literature not specifically about multinational R&D, and (3) report cases from our field work. Following these three sections (i.e., differentiation, resources, and integration), we propose a new synthesised framework for global R&D
networks, summarising our findings and comparing them with previous literature. The final section is the conclusion.

2 Research Setting: Multinational R&D in China

MNCs R&D in China has been growing remarkably since the 1990s. According to data from the Ministry of Commerce of China (MOFCOM), the number of reported foreign R&D centres in China has increased more than ten times in the last decade (Figure 1). However, it is difficult to accurately assess R&D activities in these centres because of the enormous heterogeneity among them. On the one hand, many prestigious centres are emerging, such as the GE China Technology Centre, the Intel China Research Centre, and the Microsoft Research Asia. On the other hand, there are many nominal R&D centres without any substantial R&D activities. China’s indigenous innovation strategy introduces both policy incentives for R&D investment and pressure on foreign companies to conduct R&D in China. As a result, many firms establish “R&D” centres with a few engineers but no substantial R&D activities (Schwaag-Serger, 2009). Therefore, von Zedtwitz (2004) estimated that there were 199 foreign R&D facilities in China at the beginning of 2004, while the MOFCOM data indicated 400 centres by 2003 and 700 centres by 2004.

![Figure 1: Number of MNCs’ R&D centres in China](image)

Data source: the annual data issued by the Ministry of Commerce of China (MOFCOM)

In terms of industrial distribution of foreign R&D centres in China, a survey conducted by the Ministry of Science and Technology of China (MOST) in 2007 on China-based R&D centres of the Fortune Global 500 corporations found that about 54% of these centres are doing R&D in the field of electronics and communication manufacturing (Du, 2009). Compared with several previous surveys, the information and communication technology sector has remained the biggest sector, but many other sectors have been
growing steadily, such as chemical and biomedical sectors (Du, 2009; Xue and Liang, 2008; Xue et al., 2002). The 2007 MOST survey also showed that 90% of the centres are owned by corporations from the United States, Europe, and Japan (Du, 2009). In terms of regional distribution, most centres are located in Beijing and Shanghai. At the regional level, the Yangtze River Delta harbours the largest number of foreign R&D centres in Chinese mainland (about 40%), followed by the Bohai Economic Rim (34%) and Pearl River Delta (18%) (Du et al., 2010).

The dominant type of overseas R&D in China is still adaptive R&D for better serving the local market and the manufacturing sectors. However, more and more centres are conducting cutting-edge R&D, and their strategic importance in the corporation is also rising (Liang et al., 2008; Xue and Liang, 2008). With regard to motivations driving overseas R&D in China, the market and human resources are two major factors, and the importance of the market factor is rising. A 1999 survey suggested that human resource was far more important than any other factors (Xue et al., 2001), a 2004 survey found that human resource remained the most important factor, whereas the Chinese market was almost as important as human resource (Liang et al., 2008), and the 2007 MOST survey showed that the market has become the most important factor, while human resource took the second place (Du, 2009).

China provides a good research setting for studying new developments in R&D globalisation not only because China is viewed as the most attractive destination of R&D FDI, but more importantly because of its diversity in terms of types of overseas R&D centres, industrial distribution, and regional characteristics. Furthermore, China provides a good setting for testing previous literature and synthesising previous wisdom for a more comprehensive understanding of multinational R&D. Chinas emerging market certainly provides some rationale for home-base-exploiting R&D, its recent progress in certain science and technology fields might open up opportunities for home-base-augmenting R&D, and China has always been in the centre for studying home-base-replacing R&D, reverse innovation, and host-country-based R&D.

3 Research Design

This paper aims to uncover general genres of MNCs overseas R&D in China, as well as corresponding motivations and organization structures associated with these different genres, but not to provide a quantified evaluation of multinational R&D in China. We conducted case studies for this purpose, and our research design mainly consulted with Eisenhardt (1989) and Yin (2009). In addition, for the first research question about general genres of overseas R&D, we adopted a less structured approach in order to establish new classifications of overseas R&D from our field work. For the second question about the relationship between types of R&D and driving resources, we also adopted an unstructured approach. We asked our interviewees open questions about the motivations driving their operation in China and local resources that they view as important. Our goal was to identify important resources and to uncover links between types of R&D and organizational
structures, our research approach does not look like a typical case study, because we relied heavily on previous literature of organization theory and international management to limit our investigation to several organizational and managerial aspects. Our attention for the third question was also about identifying links between types of R&D and different organizational and managerial models.

Our case studies took two stages: (1) a pilot study of six overseas R&D centres in Beijing and (2) a larger scale study of 25 centres located in six Chinese cities (including two in Beijing). We selected Beijing for our pilot study partly because Beijing has the largest number of overseas R&D centres in China (Du et al., 2010) and partly for convenience reasons. Yin (2009, p. 93) suggested that ”convenience, access, and geographic proximity can be main criteria for selecting a pilot case or cases. This will allow for a less structured and more prolonged relationship between yourself and the case than might occur in the real cases. This pilot case can then assume the role of a laboratory in detailing your protocol, allowing you to observe different phenomena from many different angles or to try different approaches on a trial basis.” Therefore, for the pilot study of six cases, we conducted interviews during a period of four months from December 2007 to April 2008 and took an intensely iterative process between theory and data.

One challenge confronting our study is the absence of any authoritative and publicly available lists of overseas R&D centres in China for specifying the population. Therefore, to identify the population, we first narrowed down to the BusinessWeek 1000 (2004) companies and then manually searched through the internet to locate their R&D centres in China (if any). To select cases for our pilot study, we selected centres in Beijing with high public visibility. For five out of the six cases, we have long-standing connections with them from our previous research.

For each of the six selected cases, we (1) collected public information from the internet and studied previous case studies of it (if any), (2) designed a unique interview protocol, (3) conducted the interview, (4) transcribed the interview, (5) studied the case and compared it with previous literature, primarily focusing on (a) the characteristics of R&D activity, (b) how different types of R&D is associated with different driving resources and organizational structures, (c) how our finding is related to previous literature. During this process, we gradually established our own classification of overseas R&D and its relationship with driving resources and organizational structures. Therefore, we also compared our theory and the data.

After the pilot study, we conducted a larger scale study consisting of another 25 centres. Eisenhardt (1989) suggested that a number between four and ten usually works well for theory-building case studies, and our pilot study consists of six cases, which is within this range. However, this study is motivated to uncover general genres of overseas R&D, and this research question is more exploratory than explanatory (Yin, 2009). For this type of exploratory question, a small sample of cases may miss some other important genres of overseas R&D, so we incorporated a larger scale case study of 25 cases. For this larger scale case study, we selected overseas R&D centres in six Chinese cities representing the most foreign-R&D-concentrated regions in the Chinese mainland: Beijing, Shanghai, Nanjing, Suzhou, Guangzhou, and Shenzhen. For specifying the population, in addition to the identified R&D centres affiliated with the BusinessWeek 1000 (2004) companies, we further searched within the High-Tech parks in these six cities to locate foreign R&D
centres. Interviews were conducted in a shorter period than the pilot study, that is, from 2008 April to May. The case study took the same procedure as described before, but added a questionnaire for data collection. We used the questionnaire as an instrument to force us go beyond our initial impressions for a more reliable within-case analysis and cross-case comparison (Eisenhardt, 1989). At this stage of larger scale study, we did identify new genres of overseas R&D, or more precisely, had to refine our classifications developed in the pilot study. However, the incremental learning is minimal as we further added new cases, so we decided to stop adding new cases.

In total, our sample of cases consists of 31 R&D centres of 24 MNCs. We followed the theoretical sampling strategy, that is, “cases are selected because they are particularly suitable for illuminating and extending relationships and logic among constructs” (Eisenhardt and Graebner, 2007, p. 27). Given the trend documented in the literature that overseas R&D is playing an increasingly important role in creating new knowledge and therefore is increasingly important to MNCs, we selected highly visible foreign R&D centres of large and successful companies. This focus on extreme situations and polar types allows us to detect emerging trends in R&D globalisation. In addition, we also included centres playing a less important role, e.g., conducting adaptive R&D or outsourcing-type R&D, in order to better replicate previous theories.

Furthermore, the selection of cases accounted for the diversities in industry, home country origin, centre age, position within the company, and geographic location (Table 1). Our selected centres are in four sectors: biotechnology, chemical, information and communication technology, and industrial. Most centres have home bases in Europe, the United States, and Japan, and four cases from other origins. These centres were established during two decades, ranging from early 1990s to late 2000s. Their different positions in the global company are: in corporate central laboratories independent to business units, within a business unit, and within a factory. The geographic locations of these centres cover the three most foreign-R&D-concentrated regions in the Chinese mainland: the Bohai Economic Rim, the Yangtze River Delta, and the Pearl River Delta. The sample is not random but diverse, which enhances the generalizability of our findings (Eisenhardt, 1989).

However, its worth noting that our sample is by no means representative to the whole population of overseas R&D in China. Our theoretical discussions will put much more weight on strategically important R&D, while the majority of overseas R&D in China might still be of peripheral nature in reality. In other words, the purpose of this study is to provide a framework for better understanding genres of overseas R&D but not to evaluate the current status of overseas R&D in China.

4 Differentiation

The first research question of this study is: What are the general genres of overseas R&D? In other words, how does MNCs differentiate their overseas R&D? In response to this question, many taxonomies of overseas R&D have been proposed (e.g. Ghoshal and Nohria, 1989; Hakanson and Nobel, 1993; Nobel and Birkinshaw, 1998). Among them the most influential one is Kuenenlerles (1997) home-base-augmenting (HBA) and home-
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<th>Sector</th>
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\(^1\)“Corporate” refers to R&D center under corporate central laboratories; “BU” refers to independent R&D center under business unit; “Factory” refers to R&D department within factory; “Other” is center contains more than one type.

\(^2\)“BER” refers to the Bohai Economic Rim, specifically Beijing in our sample; “YRD” refers to the Yangtze River Delta, specifically Shanghai, Nanjing, and Suzhou in our sample; “PRD” refers to the Pearl River Delta, specifically Guangzhou and Shenzhen in our sample.

\(^3\)“TCU” is the technology competence unit, “SCU” is the system competence unit, “AU” is the assignment unit, and “SU” is the support unit.
base-exploiting (HBE) dualistic classification. HBA aims to take advantage of scientific knowledge and infrastructures available in the host country to create new knowledge, while HBE adapts existing knowledge, which are typically developed in the home base, to support special local demand. Furthermore, the focus of overseas R&D has been shifting from HBE to HBA, in other words, the old one-directional headquarters-subsidiaries model of MNCs has been replaced by a new model, a multiple directional network model, in which knowledge is created from all over the world and integrated into the network of the corporation (Almeida and Phene, 2004; Almeida et al., 2002; Gupta and Govindarajan, 2000).

The early studies of multinational R&D were primarily based on overseas R&D within the triad nations of the United States, Europe, and Japan. As the wave of R&D globalization expanded to the developing world, scholars noticed some different dynamics of overseas R&D in developing countries, for example, the supply of low-cost personnel was found to be particularly important (Chen, 2004; Kumar and Aggarwal, 2005; Xue and Liang, 2008). Lewin et al (2009) proposed a new term, home-based-replacing (HBR), for overseas R&D in developing countries driven by low costs and human resources and functioning similar to offshore manufacturing. More recently, the phenomenon of reverse innovation has been witnessed, that is, original innovation emerges from developing countries and then spreads to the developed world, including the home country of the MNCs (Brown and Hagel, 2005; Govindarajan and Ramamurti, 2011; Immelt et al., 2009). Similarly, Wang et al (2012) noticed several types of host-country-based R&D, suggesting that the assumed base at home has also been globalised and the multinational R&D network has evolved from a single- into a multiple-based network with internationalized bases.

These different lines of research contribute to the understanding of diverse overseas R&D activities in developed and developing countries. However, these studies are not well synthesised to provide a more comprehensive and complete framework for multinational R&D, and empirical studies following one perspective without consulting the others can result in misleading and confusing conclusions. Therefore, this paper is motivated to uncover general genres of overseas R&D in China based on field work instead of imposing a pre-specified classification system.

In our field work, while finding previous theories not sufficient to explain multinational R&D in China, we find the component-system innovation framework very relevant. In addition to the radical vs. incremental classification of innovation, Henderson and Clark (1990) added one more dimension: modular vs. architectural. Modular innovation is about changing the component of a product, while architectural innovation changes the ways that components are integrated into the system. The component-system innovation classification is helpful for understanding R&D practice in MNCs. MNCs typically have both central laboratories and business unit R&D centres. Central laboratories focus on cutting-edge component technologies that may be applied to many different products, while business unit R&D centres focus on system innovation that incorporates different technologies into a new product. Several recent studies also found the modularity literature helpful to understand the structure of multinational R&D networks and acknowledged technology modularity as a macro background enabling R&D globalisation (Quan and Chesbrough, 2010; Reddy, 2010).
Another line of literature that we find inspirational is the core competence model of
the corporation (Prahalad and Hamel, 1990). Core competences provide potential access
to a wide variety of markets, make significant contributions to the perceived customer
benefits of the end product, and are difficult for competitors to imitate. One implication
from the core competence theory is that the core competence is the root of a firms
competitive advantage and therefore should be preserved within the firm, while other
peripheral activities can be outsourced (Hoopes et al., 2003; Peteraf, 1993; Prahalad and

Incorporating these other lines of literature not specifically about multinational R&D
is helpful for understanding multinational R&D, and our case studies lead to the following
differentiation structure of the multinational R&D networks (Figure 2). The structural
chart is adapted from the core competent chart (Prahalad and Hamel, 1990), but the
4.1 Technology Competence Unit (TCU)

The technology competence unit (TCU) provides the corporation with core technologies in its specialized fields for the future global market. It possesses the specialized technology competence, which is important for the corporation and can be transferred to and applied by others parts of the corporation. Many firms have independent central laboratories separated from business units to do relatively more fundamental R&D for long-term market demand. TCU is typically one branch of the central laboratories.

One example of TCU in China is TCU-ALPHA, which is under the corporate central laboratories and specialized in speech and pattern recognition technologies. Instead of adapting mature technology from the home country to support the Chinese language, TCU-ALPHA started from exploring its own brand-new technologies. Its speech and pattern recognition technologies started from supporting Chinese and English and then extended to supporting many other languages, such as Japanese, Korean, Thai, and Arabic. Such technologies used in all the corporations products are developed by TCU-ALPHA. TCU-ALPHA is working on future technologies rather than serving current market needs. Its image understanding technology project was once viewed as useless by business units because of the limited software and hardware capacity at that moment, but was successfully incorporated in the final product and became a strong selling-point three years later. Another example is TCU-BETA working on radio frequency identification (RFID) technologies based on natural language and ontology.

4.2 System Competence Unit (SCU)

In ICT and industrial sectors, a system competence unit (SCU) is the system innovator and project owner. It identifies market demand, defines the products/services, designs the system/architecture, and integrates a variety of components into final products/services. In the biotechnology sectors, a SCU is the integrator, combining a variety of disciplines (e.g., chemistry, molecular biology, cell biology, physiology, and laboratory technology) to develop effective treatments for diseases. It owns the entire process from target identification, hit identification, lead identification and optimization, to clinical trials, each of which may involve support from other R&D units. The chemical sector has a similar but slightly different process, which can be simplified as: define the desired new features, discover the materials, and design the final product to take advantage of the discovered materials. In the ICT and industrial sectors, the component is a technology module, and
in the biotechnology and chemicals sectors, the component is a certain discipline or a certain step in the process. For all sectors, system innovation is not simply the task of assembling, but it is a sophisticated process requiring significant effort.

One example of SCU in China is SCU-GAMMA, which is under a business unit and specialised in healthcare equipment development. It has the ownership of low-end products. Low-end product does not indicate low technology, but instead its development may require even higher creativity because it requires more efficient systems and components to fulfil the same functions. One of its undergoing projects is to develop a new nuclear magnetic resonance (NMR) system with significantly lower costs. This project goal cannot be accomplished by modifying existing products, but requires technological breakthroughs at both the system and the component level. Products developed by SCU-GAMMA not only serve the Chinese market: 30% of its CT apparatuses are sold in China while 70% are sold in other markets. Low-end products developed in China are popular and profitable not only in markets of China and other developing countries, but also in relatively less developed rural areas in the United States. Another example is SCU-DELTA. It develops new drugs for liver and stomach cancer, which are more common in East Asia than in the United States and Europe. R&D conducted in SCU-DELTA is not clinical trial to test existing drugs, but starts from pathology research to develop new drugs.

4.3 Support Unit (SU)

The support unit (SU) exploits existing technologies from the headquarters and conducts adaptive R&D to meet local conditions in order to better serve local special demand. It is essentially the HBE (Kuemmerle, 1997), adaptor (Nobel and Birkinshaw, 1998), technical support unit, and adaptive R&D unit (Hakanson and Nobel, 1993), which are extensively investigated in previous literature.

We also found many cases of SUs in our field work: one centre within factory supporting semiconductor manufacturing, one centre developing new tastes, scent, and colour of their nutritional supplements to meet local preferences, and one centre conducting clinical trial for their new drugs to be introduced to the Chinese market.

4.4 Assignment Unit (AU)

The assignment unit (AU) is a type of overseas R&D unit of the outsourcing/ offshoring nature, that is, it takes advantage of local low-cost human resources to establish an accessorrial workforce for its head office. AU conducts labour-intensive, cost-sensitive, and peripheral R&D. Its work directly serves the need of its head office, but not the market of the host country. As discussed in the introduction section, one problem in applying the HBE/HBA framework to classifying overseas R&D in China without integrating the HBR literature pertains to AU. AUs are creating new knowledge so they should be classified as HBA, but they have very low status within the corporation and are managed very differently from HBA described in the literature. AU is different from SU, because the latter takes mature technology from the headquarters and adapts it for local application, while the former actually creates new knowledge. In addition, SU specifically serves local
demand, but AU typically not. AU is also different from TCU and SCU, because the R&D conducted in AU is peripheral and does not serve local needs.

One example of AU in China is AU-ZETA, its manager stated that “our work is outsourcing by nature headquarters do not give us the whole project, but parts of it, and typically peripheral parts.” The business unit that owns AU-ZETA has 75% of its sales in its home country. A complete R&D chain in this company consists of demand analysis, general design, detailed design, coding, and testing. AU-ZETA starts from detailed design while higher level activity is retained in the home country. AU is not limited to software related development, but is also applicable to research. AU-ETA is under corporate central laboratories and conducts telecommunication and multimedia container formats research in China. AU-ETA focuses on technologies 3-5 years ahead of the current market demand, while research for 5-10 or more than 10 years ahead of the time is retained in the home country. AU-ETAs technologies are serving the home country market rather than the Chinese market. The motivation of its establishment is to take advantage of the local personnel supply, because this sector in the home country is relatively less attractive to scientists and engineers.

5 Resources

The second research question is: Why do MNCs do these types of R&D in China, that is, what are the corresponding local resources driving these types of R&D? A number of factors and local conditions of the host countries have been identified as important for overseas R&D, such as scientific talent, technology infrastructure, the market, previous investments in marketing or manufacturing from the firm, cost advantages, government policy incentives and regulations, intellectual property protection, and culture approximation (Gassmann and von Zedtwitz, 1998; Niosi and Godin, 1999; Odagiri and Yasuda, 1996).

Granstrand et al (1993) summarized two categories of drivers: demand- and supply-oriented. On the one hand, demand for local technological support and adaption arises with the growing overseas market and production, as well as host country restrictions (e.g., technology standards and government regulation). On the other hand, overseas R&D is attracted by the local supply of scientific and technological skills and knowledge. Similarly, Reddy (2010) highlighted three major reasons for overseas R&D in emerging economies: access to scarce S&T human resources and infrastructure, cost advantages, and access to local/regional markets.

Before discussing the important resources revealed in our case studies, it is worth noting the differences between prerequisite conditions and driving resources: Prerequisite conditions are basic elements necessary for R&D, without which impossible is R&D, while driving resources are competitive assets and advantages provided by the region. Given that MNCs have strong R&D bases in the home country and can choose from a number of overseas sites to locate its R&D centres, the host country needs some special or unique resources to be competitive and attractive to MNCs R&D.

Furthermore, different types of R&D are driven by different location-specific advantages (Kuemmerle, 1997; 1999a; von Zedtwitz and Gassmann, 2002). Our case studies
highlight three important resources: technology strength, human capital, and the market, and their importance vary across different types of R&D units. Human capital and the market are the two resources mostly valued by our interviewees, which concurs with previous survey results (Du, 2009; Liang et al., 2008; Xue et al., 2001). Furthermore, our cases suggest that human capital is particularly important for AU, and the market is important for TCU, SCU, and SU. Technology strength is not confirmed as one of the most important driving resources in our field work, but we still keep it in our discussion, partly because previous literature suggests that it is important for knowledge augmenting R&D, and partly because one of our contributions is to challenge (or add to) the link between technology strength and knowledge augmenting R&D.

5.1 Technology Strength

The competitiveness of a firm does not rely on its ability to invent or master a technology, but depends on its ability to absorb external technologies and capture these technology opportunities (Grant, 1996; Pavitt, 1998). Firms are increasingly dependent on external sources of knowledge: They establish global innovation networks for technology acquisition and monitoring and then integrate knowledge from multiple sources and dispersed locations (Almeida and Phene, 2004; Almeida et al., 2002; Gupta and Govindarajan, 2000). Furthermore, codified knowledge is only tip of the iceberg, while tacit knowledge embodied in human brain and social networks is much more important (Nonaka and Takeuchi, 1995; Pavitt and Patel, 1999). In addition, the tacit knowledge is spatially sticky and can only be accessed within the region (Lundvall, 1988; Markusen, 1996; Saxenian, 1994). Therefore, firms have to locate their R&D in regions with advanced science and technology in order to tap into the local knowledge base.

As discussed extensively in the literature, the technology strength is the most important driving factor of home-based augmenting R&D. For instance, Xerox located R&D in Grenoble, France to “learn firsthand what was going on in centres of scientific excellence in Europe” (Kuemmerle, 1997, p.66). One pharmaceutical company that we interviewed set up a R&D facility in France to do medicinal and synthetic chemistry research because of the strength of that region in this field. The TCU and SCU can be viewed as subcategories of HBA, but technology strength does not appear in our field work to be the primary driving resource, which is in line with several other recent studies (Motohashi, 2010; Sun, 2010). Aiming to build an innovative economy, China has been investing heavily in science and technology (Breznitz and Murphree, 2011; Liu et al., 2011), and China’s S&T strength has been rising remarkably in recent decades. However, China is still not a world leader in various S&T fields (King, 2004; NSF, 2007).

5.2 Human Capital

The supply of R&D personnel has long been recognized as an important driving resource for overseas R&D. However the R&D personnel supply emphasized in the literature may have different meanings in different contexts. Human resources emphasized in studies of overseas R&D in the developed world typically refer to science excellence and technology leadership (e.g. Hegde and Hicks, 2008; Kuemmerle, 1997; 1999a; Le Bas and Sierra,
2002), while human resources emphasized in studies of overseas R&D in developing countries are more focused on the supply of low-cost R&D staff (e.g. Chen, 2004; Kumar and Aggarwal, 2005; Lewin et al., 2009). In this paper, the resource of “human capital” refers to the latter, while the former is viewed as one of the “technology strengths.”

The local supply of low-cost capable personnel is a very important driving resource for overseas R&D in developing countries (Chen, 2004; Kumar and Aggarwal, 2005; Lu and Liu, 2004). Externally, technology modularity enables separating and dispersing peripheral R&D. Internally, firms are motivated to offshore some parts of R&D in places with lower costs, when these parts of the R&D are labour-intensive, and cost becomes a concern for competitiveness (Baldwin and Clark, 2000; Ernst, 2005; Ernst and Kim, 2002). In addition, the increasing shortage of capable R&D personnel in the home country also motivates firms to go abroad to augment their limited labour pool. Under this circumstance, sufficient technology personnel supply, not necessarily of low cost, is an important driving resource (Lewin et al., 2009).

Our case studies confirm that the human capital is the main driving resource for AUs. For example, AU-ZETA takes advantage of local low-cost software developers to conduct offshore R&D, and AU-ETA was established primarily because the ICT sector in its home country was not attractive to scientists and engineers, compared with other sectors such as automobile, but China had very competitive ICT researcher supply.

5.3 Market

Previous literature viewed the local/regional market as demand for adaptive R&D (Kuemmerle, 1997; 1999a; Le Bas and Sierra, 2002). Our cases also confirm that SUs are driven by the need to adapt mature technology from the home country to better serve local manufacturing and marketing.

However, the market can drive original innovation for the following four reasons. First, it is efficient to locate product ownership at the centre of a market for a balance between mass-production and customization. If a local market becomes the centre of a specialized market, (e.g., has the biggest sales or is the most lucrative), then it is efficient to develop this product mainly based on demand and conditions of this local market and then adapt this product to other markets. SCU-GAMMA locates the ownership of low-end products in China but conducts adaptive R&D in another developing country, and the reason is that the market of this developing country is not as big as that of China. In addition, system design and technology development in SCU-GAMMA is based primarily on the market demand of China but also takes into account of global conditions, because its goal is not just serving the Chinese market.

Second, innovating for the market is vital for success in a demanding and competitive market. As emphasized by many of our interviewees, adaptive R&D and simple modification is no longer sufficient to meet local demand or secure success in the Chinese market.

Third, technological standardization in a big market can put a lot of pressure on MNCs to participate in local standard setting process. Because of the size and potential of the Chinese market, China’s choice of technology standards can impose great influence on the rest of the world. As China is seeking a more active role in setting international
technology standards, many MNCs conduct R&D in China to follow and get involved in the technology standard development in China (Ernst, 2011; Forster, 2006).

Fourth, the market is also an important source of innovation. Literature viewing market as passive demand for adaptive R&D implicitly assumes a technology-push model of innovation but ignores the market-pull innovation model, which emphasizes the importance of market demand to drive not only incremental but also radical innovation (Rosenberg, 1969; Schmookler, 1966; Sherwin and Isenson, 1967). In the context of multinational R&D, the reverse innovation literature has provided many examples of how the demanding local market in developing countries drives original innovation, which latter spreads back to the home country and achieves great commercial success.

The most important driver for TCUs in our sample seems to be the market, which is also in line with recent surveys (Du, 2009; Liang et al., 2008). Our interviewees emphasize that the main reason for setting up these R&D centres in China is because of the market. The research fields of both TCU-ALPHA and TCU-BETA specifically relate to the needs of the Chinese market. One speciality of TCU-ALPHA is the handwriting recognition technology, which is popular in China because of the complexity of the Chinese characters; using keyboard to input Chinese can be very inconvenient. Similarly, the vastness and density of information processing and communication in China have led to a number of challenges for telecommunication technologies, which drives the R&D in TCU-BETA. Furthermore, the president of TCU-BETA is very satisfied with Chinese researchers except for one issue, that is, “they [Chinese researchers] are too devoted to technology itself, but lack of the sense of innovating for the market, lack of the ability to view themselves as users and identify what special demand they have.” In other words, TCU-BETA is expecting its staff to innovate for the market.

The story is similar for SCUs, for example, SCU-DELTA works on the liver and stomach cancer, which is much more common in East Asia than in the United States and Europe. SCU-GAMMA locates the ownership of low- and high- end healthcare equipment in China and the United States respectively, because they are the centre of these two markets respectively.

6 Integration

The third research question is: How do MNCs integrate their overseas R&D in China? Lawrence and Lorsch (1967) defined the central task of organizing as differentiating and integrating. They explained differentiating as segmenting an organization into distinct specialized subsystems, and integrating as “achieving unity of efforts among the various subsystems in the accomplishment of the organizations task” (p.4). The growing volume and importance of overseas R&D raises critical challenges to MNCs. Therefore, an effective integration mechanism is needed to cope with these challenges and to achieve unity of efforts among differentiated and dispersed R&D units. A variety of managerial issues have been investigated, such as headquarter control versus subsidiary autonomy, communication and coordination, global network structure, and human resource management (Ghoshal et al., 1994; Gupta and Govindarajan, 1991; Hakanson and Zander, 1988).

According to the contingency theory, different integration mechanisms are needed for
different types of task in process (Burns and Stalker, 1961), and determining factors include task uncertainty, interdependence, and unit size (van de Ven et al., 1976). Intertwined with this line of research is the power relationship within an organization, which tackles two issues: The first follows Webers (1947) legacy, focusing on the degrees of structural integration such as centralization, formalization, and socialization, and the second traces back to March and Simon (1958) and Thompson (1967), focusing on conceptualizing and measuring processes of coordination. Furthermore, the power status of the subunit in the organization depends on the importance of resources that it brings in (Hickson et al., 1971; Salancik and Pfeffer, 1974), and these resources include ability to cope with uncertainty, low substitutability, and centrality (Hickson et al., 1971). In other words, the ability of bringing in important resources gives a subunit higher power status over other subunits (Pfeffer and Salancik, 1974; Salancik and Pfeffer, 1974).

The contingency approach and the internal power approach have proven useful for understanding the internal differentiation within multinationals and the deployment of different organizational and managerial models (Ghoshal and Bartlett, 1990; Ghoshal and Nohria, 1989; Nobel and Birkinshaw, 1998). Following this line of research, we also focus on the control and communication issues in the management of multinational R&D in China and explore the question of how these integration mechanisms differ across different types of the R&D. In addition, previous studies of communication issues have explored both internal and external communications of multinationals. Almeida and Phene (2004) argued that what makes communication of overseas subsidiaries interesting is that overseas subsidiaries are simultaneously embedded in two knowledge networks: the internal MNCs network and the external network in the host country, and their study focused on the influence of external knowledge. In addition, communication with external innovators is particularly relevant to knowledge spillovers from MNCs to the host countries, which is another important topic in the multinational R&D literature (Ernst and Kim, 2002; Feinberg and Gupta, 2004; Padilla-Perez, 2008). Therefore, we make external collaboration an independent section separated from the communication section.

6.1 Control

Control can be defined as “regulation of activities within an organization so that they are in accord with the expectations established in policies and targets” (Child, 1973, p.117). Ghoshal and Nohria (1989) investigated three control modes of managing overseas subsidiaries (not limited to R&D subsidiaries): centralization (decision-making by headquarters), formalization (decision-making through rules and procedures), and normative integration (decision-making through establishing common expectations and shared values). They also explored the determining factors: local resource levels and environmental complexity. Nobel and Birkinshaw (1998) investigated these three decision-making modes for managing overseas R&D subsidiaries specifically, and their explanatory factors included costs and strategic importance of the R&D subsidiary.

How would different control modes be deployed in different types of R&D centres? From the internal power perspective, R&D centres which bring in more important resources would have higher power position within the organization (Hickson et al., 1971;
Salancik and Pfeffer, 1974), in other words, they would have higher level of autonomy and lower level of centralized decision-making. Furthermore, Ghoshal and Nohria (1989) added another explanation from a cost-benefit perspective. Centralization has the lowest administration costs, while normative integration the highest. From an efficiency point of view, administration modes with higher costs will only be adopted in subsidiaries with higher strategic importance. According to these explanations, we would expect that TCU s and SCU have higher autonomy while SUs and TUs have more centralized decision-making.

In our case studies, we focus on decision-making pertaining to R&D project selection. TCU s and SCU s are coping with great uncertainties from both the technology and the market sides, they cannot be easily substituted by other R&D units because of their access to local competitive resources, and they occupy the core of the corporate R&D network. Therefore, they are also offered with higher autonomy for project selection. For both TCU-ALPHA and TCU-BETA, their specialties were defined by their headquarters when they were established, but within their fields, they have the autonomy to decide what projects to work on. Project ideas are initiated in brainstorming with researchers working in the unit. Proposal to the headquarters and approval from headquarters is required before starting the project, but only to avoid duplication of efforts. All their proposals are approved unless there are duplications. Similar stories are found for SCU s.

However, AUs are strictly controlled by their head offices due to their offshore insourcing nature. For example, both AU-ZETA and AU-ETA receive specific requests/commands from their head offices and submit their R&D results back to their head offices. Their modules of technology are incorporated into a bigger system by their head offices. Similarly, SUs also has low autonomy. The head offices make decisions about what products to launch and what technologies to use, while SUs implement these decisions.

6.2 Communication

Communication is viewed by De Meyer (1991) as a crucial component for successful management of overseas R&D, and a variety of mechanisms are needed to enhance communication between geographically dispersed R&D sites. Multiple directions of communication are to be managed between an overseas R&D unit and other internal actors such as the headquarters, sister R&D units, and other functional units (Ghoshal et al., 1994; Gupta and Govindarajan, 1991; Nobel and Birkinshaw, 1998). Therefore, we focus on the communication flow between focal R&D units and other internal divisions.

TCU s are observed to have intense interaction with other R&D units within the corporate R&D network. Both TCU-ALPHA and TCU-BETA actively participate in conferences and meetings with other R&D units. They also frequently visit and receive visitors from other units. They collaborate with other R&D units based on strength complementarity, and there are three main setups of such collaborations: (1) they are approached by others to provide assistance in their speciality, (2) they collaborate with others equally, and (3) they lead the collaborative project. TCU s also have close connection to business units since they are expected to make contribution to business success. They may push their technologies to business units for commercialization, or be requested by business units to solve sophisticated technology problems. The manager of TCU-ALPHA has
established close personal connections with local business division managers, to facilitate pushing technologies into final products. Interaction with marketing departments is also important, since TCU cases found in China are primarily driven by the market demand. TCUs brainstorm to initiate new projects typically involve intense interaction with the marketing divisions.

SCUs also have intense communication with other internal actors. SCU-GAMMA views communication with other R&D units crucial to its functioning. In the annual brainstorm meeting, all central laboratories and business unit R&D branches gather together, the former push technologies to business units, and the latter present innovation opportunities pulled by the market. From these brainstorm, opportunities of integrating cutting-edge technologies into final products emerge. In terms of collaboration models, SCU-GAMMA owns the system and seeks assistance in various technology modules from other R&D units. Although it owns the system, it does not pursue the goal of having all the components developed within SCU-GAMMA. Instead, it uses technology modules from the corporations “best” centres for that technology. Similarly, SCU-DELTA does not invest in all the facilities needed for developing drugs. It would have its chemical tests and compound screenings conducted in R&D facilities in other countries which are specialized in these fields. In terms of communication with other functional units, SCUs are even closer to the manufacturing and marketing divisions than TCUs.

However, AUs do not have frequent interaction with other R&D units or functional divisions. They are strictly embedded in the network of their head offices and have almost no interaction with any other innovators. They function as a processor, receiving commands from the head office as input and then submitting R&D results as output. They may work together with a variety of teams on one big project, but they do not need to interact with others, since technology modules are independent with each other. The communication patterns of SUs are quite similar to that of AUs, except that they are closely connected with local manufacturing or marketing divisions.

### 6.3 External Collaboration

Overseas R&D centres play an important role of connecting the knowledge network of the corporation and the network of the host country (Almeida and Phene, 2004; Kenney and Florida, 1994). Intense interaction and collective learning with local innovators is the key to local sticky knowledge (Lawson and Lorenz, 1999; Lundvall, 1988; Markusen, 1996). Theoretically, R&D centres performing original innovation are expected to have high level interaction with external innovators in order to tap into local innovation networks. For example, TCUs and SCUs would be expected to have close interaction with local firms and universities so that they can take advantage of local innovation resources and achieve higher level of innovativeness. However, a collaborative relation depends on efforts from both sides: not only foreign R&D centres but also local innovators. In our case studies, we found that in many cases, foreign R&D centres external collaboration is largely constrained by the availability of local collaborators.

TCUs and SCUs are observed to be very enthusiastic about collaborating with local innovators, for example, TCU-ALPHA collaborates with Changhong on digital TV chips and FAW on auto electronics. However, collaboration with local innovators is largely
constrained by the availability of collaborators. Universities are the most important collaborators, while collaborating with Chinese firms are not very frequent. In addition, the prevailing model of collaboration with universities is to solve very specific technological problems for the firm, rather than following and monitoring technology advancement in universities. This reflects the weakness of the Chinese innovation system. Furthermore, an innovative and dynamic local network has not yet emerged; industrial clusters in developing countries do not have dynamic interactions and are merely agglomerations of firms without collective learning (Chaminade and Vang, 2008; UNIDO, 2001). Therefore, there is seldom dynamic local knowledge network attracting MNCs to establish external collaborations.

Different from TCUs and SCUs, AUs serve as an accessorial workforce for their head offices. They only employ local R&D personnel to do the work and have no interaction with external innovators in the host country. SUs do not seek local collaboration either, but they may interact with local suppliers to facilitate local production.

7 A New Framework of Global R&D Networks

Based on our cases, we propose a new framework to understand differentiation and integration of multinational R&D in China (Figure 2 and Table 2). Underlying this framework are two casual propositions: (1) different types of overseas R&D are driven by different local resources, and (2) the integration mechanisms vary across different R&D units.

Figure 2 presents the differentiation structure of the multinational R&D network. The technology competence unit (TCU) and the system competence unit (SCU) occupy the core of the R&D network and are specialized in technology component and system innovation respectively. The assignment unit (AU) serves as an outsourcing unit to conduct periphery R&D. The support unit (SU) transfers and adapts mature technology to better serve the local demand. Furthermore, these four types of R&D units form a complete R&D system covering all stages of the life circle of R&D: using local talent and market knowledge to initiate innovation, employing local personnel to carry out R&D, and adapting resulting technologies to serve local, regional, and global markets.

Enfolding literature, that is, “comparison of the emergent concepts, theory, or hypotheses with the extant literature,” is one essential component for theory-building cases studies (Eisenhardt, 1989, p. 544). Therefore, we discuss the similarities and conflicts between our framework and the literature. Compared with the home-base-exploiting (HBE) and home-base-augmenting (HBA) classification, HBE is equivalent to SU, whereas HBA is further classified into TCU and SCU in order to differentiate between component and system innovation. At the time when our case studies were concluded, the term of home-base-replacing R&D (HBR) (Lewin et al., 2009) has not yet been proposed explicitly as a different type of overseas R&D in addition to HBE and HBA, although many studies have followed the offshore manufacturing perspectives to study overseas R&D in developing countries. Nevertheless, this HBR literature is also consistent with our new framework, and HBR can be classified as AU in our classification. However, our AU includes overseas R&D taking advantage of local low-cost personnel supplies for not only labour-intensive
development (i.e., HBR) but also for original research. In addition, the paper popularized the idea of reverse innovation (i.e., Immelt et al., 2009) and the host-country-based R&D paper (i.e., Wang et al., 2012) have not yet been published when our case studies concluded, although a similar ideas, innovation blowback, was proposed by Brown and Hagel in 2005. The reverse innovation and host-country-based R&D theses are also consistent with our new framework, that is, they can be understood as HBA in developing countries driven by the market demand rather than the technology strength, and therefore can be classified as TCU or SCU.

Different R&D units are driven by different local resources. Previous literature suggests technology strength, the market, and human capital as important drivers of HBA, HBE, and HBR respectively. In addition, reverse innovation is driven by local demanding market conditions. Our findings partially agree with previous literature. Human capital is confirmed to be important for AU, and the market is important for SU. However, the market can also drive original innovation (i.e., TCU and SCU) when the market is lucrative, heterogeneous, demanding, and competitive.

Different R&D units are integrated by different mechanisms. Our case studies suggest that TCU and SCU have higher autonomy and more frequent interaction with other internal actors, but collaboration with external innovators is largely constrained by the availability of local collaborators. On the other hand, AU and SU are very strictly controlled by their head offices and have infrequent interaction with other R&D units, other functional divisions, or external innovators. These findings are also consistent with the literature. However, its important to make the distinction between HBR and HBA. Simply applying the HBE/HBA classification would typically classify HBR as HBA since new knowledge is created, particularly when original R&D is conducted, but HBR does not have the high managerial status associated with HBA as suggested by Kuemmerle (1997). In addition, its also important to further distinct between TCU and SCU, because SCUs integrates different technology components, and play a role of owner or leader beyond the boundaries of technological R&D.

However, our study has several limitations and calls for further research. First, given our theoretical sampling strategy and limited sample size, we are not able to provide an accurate evaluation of the current status of multinational R&D in China. Second, this study is about multinational R&D in China but lacks an international comparison perspective. In-depth case studies of other countries, particularly other developing countries, are needed to better synthesise previous theories and new phenomena in developing countries. Third, given the limited number of cases in biotech sectors available in China, data collected about biotech are much less than ICT related sectors. Although the biotech cases fit well in our proposed framework, our framework does not provide more detailed insights into the understanding of biotech dynamics. Therefore, more cases in biotech as well as other sectors are needed to gain more variations for theory building. Fourth, the approach adopted in this paper is relatively static, and this study lacks a dynamics perspective to investigate evolution of individual R&D centres at the micro level (Birkinshaw and Hood, 1998). It may take a long time for a R&D unit to accumulate competence and become a TCU or SCU, so its evolving process deserves more investigation. Fifth, this study also lacks a historical perspective at the macro level to reveal general trend of R&D globalisation and differences between several waves of R&D globalisation (Reddy,
It might be informative to explore differentiation and integration differences between R&D centres established in different years.

8 Conclusion

This paper found four types of multinational R&D units in China: TCU focuses on component innovation, SCU focuses on system innovation, AU utilizes local human resources to support R&D in the head office, and SU adapts mature technology to support local marketing and manufacturing. These four types of R&D constitute a complete R&D system, with TCU and SCU at the core, AU as an accessorial workforce, and SU as a technology transfer channel. MNCs differentiate their R&D units into these four types to utilize local-specific advantages and adopt different integration mechanisms to manage functionally differentiated and geographically dispersed R&D activities.

This paper makes the following contributions. First, this paper proposes a new framework for understanding multinational R&D, which synthesises several lines of previous literature. Early literature based on multinational R&D in developed countries has established relatively systematic theories for explaining multinational R&D not only in developed countries but also in developing countries. Others, following a different tradition and viewing overseas R&D in developing countries as an extension of manufacturing outsourcing, have also added insights into understanding some distinct features of overseas R&D in developing countries. Furthermore, the reverse innovation and host-country-based R&D theses focused on emerging phenomena that MNCs conduct original innovation in developing countries following a market-pull model. However, these different lines of literature is not well-synthesised, and applying one perspective to guide empirical studies without incorporating others would lead to misleading interpretations and conclusions. Based on our field work, we establish a new classification system for multinational R&D, which provides a more systematic understanding of the general types of overseas R&D.

Second, this study has implication for future research, that is, it might be very useful to integrate different models of innovation for a better understanding of multinational R&D. Previous innovation studies have long recognized that original innovation can be driven by not only technology but also market (Mowery and Rosenberg, 1993; Sherwin and Isenson, 1967). Furthermore, both the technology-push and the market-pull models have problems and an integrated non-linear model is helpful for a complete understanding of innovation (Arthur, 2007; Freeman and Soete, 1997; Mowery and Rosenberg, 1979). This idea has also been integrated in the innovation management literature (Bernstein and Singh, 2006; Brem and Voigt, 2009). However, previous multinational R&D literature implicitly assumes a technology-push linear model of innovation and views the market as demand for adaptive R&D. However, our findings suggest that the market demand is also important for original R&D at both component and system levels. Furthermore, original overseas R&D in China is primarily driven by the market. By incorporating the market-pull innovation model, we contribute to the understanding of the role of the market in driving overseas R&D. For future research, it might be helpful to incorporate other models of innovation instead of implicating assuming a technology-push linear model.
References


Table 2: Multinational R&D unit comparison

<table>
<thead>
<tr>
<th>Differentiation</th>
<th>Technology Competence Unit</th>
<th>System Competence Unit</th>
<th>Assignment Unit</th>
<th>Support Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core technology provider for global market</td>
<td>Integrator, project owner, serving global market</td>
<td>Accessorial workforce</td>
<td>Adaptor to support local market and production</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Driving Resource</th>
<th>Technology Strength and Market</th>
<th>Technology Strength and Market</th>
<th>Assignment Unit</th>
<th>Support Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freely choose projects</td>
<td>Own projects</td>
<td>Follow command</td>
<td>Human Capital</td>
<td>Market</td>
</tr>
</tbody>
</table>

| Control          | Communication                  | Communication                  |                |              |
|------------------|--------------------------------|--------------------------------|                |              |
| Freely choose projects | Own the system, and be supported | Support local demand           | Intensive      | Infrequent   |

| –Other R&D       | Collaborate, lead and support | Own the system, and be supported | Infrequent | Infrequent   |
| –Business Division | Transfer technology           | Lead products and production   | Infrequent   | Support local demand |
| –Marketing       | Intensive                     | Intensive                      | Infrequent   | Support local market |
| External Collaboration | Some                        | Some                           | Infrequent   | Infrequent   |