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<td>Author(s)</td>
<td>劉娜娜</td>
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<td>Citation</td>
<td>劉娜娜：人間文化研究科年報（奈良女子大學大學院人間文化研究科年報）第29號</td>
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<tr>
<td>Issue Date</td>
<td>2014-03-31</td>
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<td>URL</td>
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Literature Review on the Geography of R&D Activities

Li Nana*

1. Introduction

In modern economic growth theory, research and development (R&D) activities and the subsequent creation of new knowledge are the driving forces for long-term regional growth (Koo and Kim 2009). Many studies have also recognized the role of R&D activities in maintaining enterprise competitiveness and improving regional innovation (Asheim et al. 2003; Feldman 1994). Given the widespread assertions that industrial R&D activity fosters regional growth, regional scientists, economic geographers, and policy analysts alike have intensified their efforts in recent years to uncover the underlying determinants of its geographic distribution (Erken and Kleijn 2010; Sivitanidou and Sivitanides 1995). Multinational corporations (MNCs), in particular, play a positive role in R&D activities and international technology transfer, and their R&D strategy and distribution in home and host countries have attracted considerable attention in previous studies (Cantwell and Piscitello 2002, 2005; Niosi 2003; Unctad 2005).

Attempts to explain R&D activities have resulted in a number of research findings in diverse fields, such as R&D spillovers and regional innovation and production (Simonen and McCann 2010; Audretsch and Feldman 1996; Cantewell and Piscitello 2002), R&D location factors (Niosi 2003; Autant-Bernard 2006; Erken and Kleijn 2010), enterprise R&D strategy and transfer of knowledge (Yu and Tong 2003; Sivitanidou and Sivitanides 1995), and enterprise spatial organization and distribution of R&D institutions (Akimoto 1989; Du 2001; MRI 2002). This paper focuses on these dimensions of the literature on R&D activities.

This paper aims to review and summarize the most important ideas and arguments in the research findings on R&D activities, particularly focusing on the geography of enterprise R&D institutions, to provide the basis for a critical examination of R&D issues. The rest of the paper is organized as follows. The next section first outlines the relationship between R&D activities and regional growth, and then provides some theories on clusters and innovation. Section 3 introduces the location factors and patterns of multinational R&D. Based on the discussion, section 4 further elaborates on enterprise R&D location within countries. The last section provides the concluding remarks.

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2. R&D Activities and the Geography of Innovation

2.1 R&D activities and regional growth

R&D activities and its institutional setup (i) create economic efficiency directly by building R&D institutions, (ii) produce spillover effects on regional industries through R&D activities and economic revitalization through the commercialization of R&D results, and (iii) produce beneficial effects on other firms by locating R&D institutions nearby, performing R&D activities and developing business relationships among firms (Osaka Prefecture Institute for Advanced Industrial Development 2007).

Although extensive research has found that R&D activities contribute to regional growth significantly, empirical evidence does not always corroborate this view. For example, Koo and Kim (2009) empirically analyze the correlations between R&D spending and the growth of gross state products (GSP), and find seemingly weak or nonexistent association between R&D and regional growth. From a research on an agglomeration of private research institutions in Tsukuba science city, Nakagawa et al. (1992) find that commodity interflow among these institutions is relatively low. Sternberg (1996) also confirms that government policy has always favored balanced regional growth. However, he points out that the unintended spatial effects of R&D expenditures play an important role, especially in the early stage of technology-oriented growth. In more established high-tech regions, by contrast, commercial markets gain importance, reducing the significance of government R&D. For mature and very large high-tech regions, state technology policies represent, at best, only a less important determinant of regional growth.

The above discussion shows that R&D is only one of the factors in the development of a high-tech region. In the absence of other factors, R&D expenditures by the government can hardly be expected to promote industrial development (Feldman 1994). The higher the level of knowledge commercialization and retention factors (such as entrepreneurial activity, university research, human capital and industrial diversity), the greater importance the industrial R&D has for regional growth. This implies that newly created knowledge can contribute to the regional economy only when various other factors are also present in the region (Koo and Kim 2009).

2.2 R&D spillovers and the geography of innovation

2.2.1 Knowledge spillovers and geographic proximity

Technology and R&D spillovers are characterized by significant externality. The knowledge acquired through R&D activities is tantamount to public property. Thus, R&D institutions are not the exclusive beneficiaries. Knowledge diffused among rival firms or linked entities can produce externality even without entering the market (Shinbo et al. 2005). Thus, (i) firms can acquire information created by others without paying for that information in a market transaction, and (ii) the creators (or current owners) of the information have no effective recourse, under prevailing laws, if other firms utilize the information so acquired (Grossman...

Geographic proximity promotes knowledge spillovers positively. Location and geographic space are key factors in explaining the determinants of innovation and technological change (Audretsch and Feldman 2003). Intellectual breakthroughs must cross hallways and streets more easily than oceans and continents (Glaeser et al. 1992). Such proximity accelerates innovation diffusion, facilitates investment in skills, and encourages the development of supporting industries. Firms whose neighbors do much R&D produce more patents, resulting in a positive interaction that gives high-R&D firms the largest benefit from spillovers. Although the net effect is positive for high-R&D firms, firms with R&D below the mean are worse off, overall, from the R&D of others (Jaffe 1986).

In addition, social interaction also plays an important role in knowledge spillovers. As Doloreux and Parto (2004) have mentioned, innovation can be regarded as embedded in social relationships. This kind of face-to-face contact, and even frequent and repeated communication, is the best way to transfer knowledge. In frequent social interaction, observation, and communication, the transmission of knowledge, particularly, tacit-knowledge costs the least.

2.2.2 Clusters and innovation

According to another viewpoint, clusters, more than geographic proximity, can promote innovation. Porter (1998) describes clusters as geographic concentrations of interconnected companies and institutions in a particular field. He explains the relationship between clusters and innovation as follows:

● Clusters play a vital role in a company’s ongoing ability to innovate. The ongoing relationships with other entities within the cluster also help companies to learn early about evolving technology, component and machinery availability, service and marketing concepts, and so on. Such learning is facilitated by the ease of making site visits and frequent face-to-face contact.

● Clusters do more than make opportunities for innovation more visible. A company within a cluster often can source what it needs to implement innovations more quickly. Local suppliers and partners can and do get closely involved in the innovation process, thus ensuring a better match with customers’ requirements.

● Companies within a cluster can experiment at lower cost and delay large commitments until they are more assured that a given innovation will pan out. In contrast, a company relying on distant suppliers faces greater challenges in every activity it coordinates with other organizations.

However, although Jacobs (1969, cited in Glaeser et al. 1992) also favors local competition, which can speed up the adoption of technology, she believes that the most important knowledge transfers come from outside the core industry. Variety and diversity of geographically proximate industries, rather than geographical specialization, promote innovation and growth. Glaeser et al. (1992) also argue that industries have a life cycle and their
externalities are important only at the beginning when new products are introduced. Spillovers might be very important when a new industry is born and organizes itself in one location, but unimportant as this industry matures and geographical proximity becomes less important for the transmission of knowledge. Inter-industry knowledge spillovers are less important for growth than are spillovers across industries, particularly in the case of fairly mature industries.

3. Location of Multinational R&D

The location of R&D centers is determined by a comprehensive set of factors, including reasonable distance from headquarters and other institutes. Many studies show that R&D is concentrated in a few regions in either developed or developing countries. Moreover, MNCs are the main contributors to long-term R&D activities, and the distribution and location of their R&D institutions have attracted considerable attention. This section discusses some of the R&D location decisions of MNCs.

3.1 Location determinants of MNCs’ R&D centers

Large local markets, fully developed infrastructure, a policy environment favorable for investment, a relatively high level of technology, and substantial R&D resources of the host country are generally considered important to attract R&D investment from MNCs (Kumar 2001). Human capital and level of intellectual property protection are also decisive factors for overseas R&D investment (He and Wang 2006). Zheng (2000) concludes that (i) direct application of R&D results in the branch plants of host country and (ii) cultural variety and openness, and a vibrant industrial climate, attract R&D investment from MNCs. Geographical and cultural proximity is also a major determinant of the country location pattern of overseas R&D (Niosi 2003).

3.2 Location types of MNCs’ R&D

The quality and extent of externalities that accrue from MNCs activities are associated with their investment motivation, which needs to be spatially linked to the location advantages available to them (Narula and Dunning 2000; Cantwell and Narula 2001). Some researchers classify R&D organizations into different types according to their investment motivation and function, as shown in Table 1. Many of these types represent the international R&D function at different stages.
For example, Ronstadt (1984) classifies multinational R&D into four types: transfer technology unit (established to help certain foreign subsidiaries transfer manufacturing technology from the parent while also providing related technical services for foreign customers), indigenous technology unit (established to develop new and improved products expressly for the foreign market), global technology unit (established to develop new products and processes for simultaneous application in major world markets of the company), and corporate technology unit (established to generate new technology of a long-term or exploratory nature expressly for the parent) (Odell 2006).

Saur-Amaral and Borges Gouveia (2008) summarize the historical evolution of multinational R&D organizations (Figure 1). In the beginning of the 1980s, centralized structures were the most frequent. At this stage, technology was developed at home, and specific R&D units were set up abroad to support technology transfer and adaptation to local market demands. Between the mid-1980s and the beginning of the 1990s, the most frequent structures were polycentric. R&D units were decentralized and they had distinct goals, resources and coordination patterns. In the second half of the 1990s, international R&D structures transformed into global integrated networks as strategic technological alliances started to involve external partners and focus on international learning. In the year 2000, firms started to source technology towards exploration for assets-augmenting, and developed coherent integration strategies and multiple learning centers for this purpose. At this stage, cooperative arrangements and networks help improve absorptive capacity, facilitating flexible and fast connection between distributed competency centers.

Moreover, different types of multinational R&D show diverse location preferences. For
Figure 1. Historical Evolution of the Structures of International R&D Organization

Source: adapted from Saur-Amara and Borges Gouveia 2008.
instance, Du (2001) points out that the production-supporting type, usually located close to existing factory sites, is generally found in countries with huge markets. The technology-tracking type of R&D is most strongly influenced by the competitiveness and science and technology levels of the host country. Thus, it favors nations or regions with high levels of technology. The resource-seeking type is preferably located in regions with an abundance of talent.

Most previous studies on multinational R&D focus on the common location factors and R&D’s function in the respective of trade and investment. However, regional and national differences and enterprise diversity are largely neglected. Moreover, detailed studies on the spatial relationship between R&D and other organizations and agencies are extremely limited.

4. Location of Enterprise R&D Institutions at National Scale

The previous section discusses location determinants and spatial evolution of MNCs’ R&D organizations and explains how the host country can attract more R&D activities of MNCs. However, some researchers argue that knowledge spillovers of multinational R&D are very limited and R&D performed at home is significantly more productive than that undertaken abroad (Lychagin et al. 2010). No significant spillover effects of foreign investments on technological innovation are observed, and advanced technologies cannot really be imported from foreign countries but can only be developed internally (Sun and Du 2010). Therefore, this section discusses national and local enterprise R&D activities.

4.1 R&D distribution on a national scale

R&D institutions or centers show high geographic concentration within countries and tend to be distributed in metropolitan areas. Nakagawa (1996) points out that most Japanese R&D institutions are highly concentrated in Tokyo and the surrounding areas. Although R&D institutions in Japan were once decentralized away from metropolitan areas to nonmetropolitan areas, they have now returned to the metropolitan areas (Ishigami 1986; Sato 2004; MLIT 2006).

Malecki (1979) points out that large firms’ location choice, especially R&D location choice and its changing role in technology, has a great impact on regional economic development. His study on the location of 330 large firms demonstrates that most R&D institutions are located together with headquarters, but they do not show as high geographic concentration as headquarters do. Moreover, although R&D institutes were mainly distributed in New York and New Jersey areas, they have diffused to other areas, especially the Los Angeles metropolitan area.

4.2 R&D location factors

The location factors of regional or local R&D have also been discussed. Their location preferences are similar to those of multinational R&D, abundant research personnel, preferential policies, and proximity to other firm organizations, for example. Lund (1986, cited in Li 2012) concludes that proximity to headquarters, abundant research personnel, high quality

— 51 —
of life and complete community facilities, proximity to the production plant, and proximity to universities and research institutes are the five leading R&D location factors. In fact, these factors are interrelated and interact with each other. For instance, university or national R&D centers are generally located in the regions with a concentration of high-tech talent, where many high-tech companies and R&D institutions are distributed. Moreover, these regions have beautiful surroundings and complete infrastructure facilities; and their residents enjoy high-quality community life.

Using industrial and behavioral location theories, Nakajima (1989) systemizes R&D location theories in terms of both agglomeration and dispersion forces (Table 2). The core idea in Nakajima's (1989) theories is how to locate R&D sites for the purpose of profit maximization and fast commercialization of research results. He considers the location factors that lead to the concentration of R&D in a few metropolitan regions, access to information sources and highly-qualified talent, easy transport system and face-to-face communication between researchers and partners, and preferential policies, for example. In order to save cost and fully utilize equipment and buildings, proximity to headquarters and other intra-firm organizations are extremely important. In particular, many R&D institutions tend to locate close to headquarters, whereas those developing short-term products or exploiting production technology are usually located near or within production plants.

Table 2. Location Theories on Enterprise R&D

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<th>Examples of Location Factors</th>
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<tr>
<td>Agglomeration force</td>
<td>Information source (university, government, market, partners and competitors); Pool of research personnel; Industrial agglomeration; Face-to-face interaction; Cooperative research; Easy transportation system; Supporting policies and preferential tax; etc.</td>
</tr>
<tr>
<td>Intra-firm factors</td>
<td>Cost saving; Management efficiency; Exchange of information; Equipment sharing; etc.</td>
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<tr>
<td>Dispersion force</td>
<td>Information leakage; Land scale and land cost; Quality of life environment; etc.</td>
</tr>
<tr>
<td>Intra-firm factors</td>
<td>Enlargement of firms; Internal divisions of labor; Commercialization of research result; etc.</td>
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Source: compiled by author according to Nakajima (1989).

As land cost increases in the high-concentration regions, decentralization of R&D to suburbs is observed. However, enterprise R&D institutions are not as sensitive to land cost as are production plants (Mano 1987). Moreover, in regions with a large amount of information, firms have difficulty learning from their partners (Sampson 2007), which is another factor leading to R&D diffusion. In addition, as the firm grows, internal divisions of labor and hierarchical reorganization take place, leading to a spatial separation of R&D and affecting R&D location.
relationships with other departments.

R&D location can also be explained by the theory of "social capital." As noted in section 2, knowledge spillovers are embedded in social relationships. Therefore, the R&D location decision is, in a manner of speaking, a social capital choice, as well. Maskell (2000, cited in Westlund 2006) describes this social capital implication as follow: "In a knowledge-based economy the perhaps most significant rent originates from the way in which the easy exchange of knowledge enhances enterprises’ innovative capabilities. Reducing your development to commercialization time is often worth virtually whatever you have to pay and social capital contributes by cutting the expenses and reducing the time needed to benefit from knowledge residing elsewhere."

Maskell (2000) links social capital not only to the enterprise’s internal knowledge production but also to knowledge exchange between enterprises that have some kind of production-related links. These links, which are obviously important in R&D projects, are summarized in Figure 2 (Westlund 2006). Social and non-formalized links, between enterprises that have production relations with each other, enlarge the flows of knowledge and information. Moreover, feedback, from the enterprise to its suppliers and to the enterprise from its customers, is increased and speeded up. Obviously, Maskell’s views of valuing easy exchange and reducing time are consistent with Nakajima’s (1989) ideas of cost saving and profit maximization.

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<th>Social links to</th>
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<tr>
<td>• Suppliers</td>
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<td>• Demanding, collaborating customers</td>
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<td>• R&amp;D-partners</td>
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| • Faster access to information and knowledge |
| • Lower information and knowledge costs |
| • Increased supply of information and knowledge |
| • Improved quality of information and knowledge |

| • Faster dialogue with suppliers, customers and partners |
| • Improved quality of dialogue |

| • Faster innovation process |
| • Higher quality of innovations |
| • Increased innovation potential |

Figure 2. Summary of production-related social Links and their effects

*Source*: adapted from Westlund 2006.
Furthermore, the “image” of the place is an increasingly essential factor to attract R&D (Li 2012). R&D requires clusters of highly educated workers or, alternatively, lifestyle amenities that are attractive to this pool of talent, which plays a critical role in shaping the interurban geography of R&D labs (Kilvits 2012; Sivitanidou and Sivitanides 1995). If the living environment is satisfactory only in some regions, investment-intensive new high-technology, high-value-added jobs are created only there. Only top specialists and skilled workers in these regions will benefit from these, not the “ordinary people” in other regions. Such structural changes may even increase economic, social, and regional stratification (Kilvits 2012).

4.3 R&D location types

Functional and locational diversities of R&D institutions are due to various factors, such as those described above. R&D functions, location factors, and R&D locations affect each other. As stated above, previous studies have focused on MNCs’ R&D from the viewpoint of R&D functions in different countries and stages. Similarly, MRI (2002) analyzes the functions of R&D institutions within a country and divides them into three types:

(i) Technology-solution R&D is set up for the purpose of technology solutions. It includes central labs, specialized labs for different departments, and other organizations developing new products. Many enterprises launch R&D activities and locate R&D institutions in this manner.

(ii) Regional R&D is mainly established to support production, but regional barriers are extremely difficult for technology to cross in this way.

(iii) Hybrid R&D evolves as the enterprise grows in size and spreads across regions. Hybrid R&D is the most popular type because an entire R&D institution cannot be put together as a one-time project but is established gradually. However, repeated establishment of R&D institutions with the same functions easily leads to low efficiency.

R&D location diversities include not only spatial differences but also location relationships with other organizations (Figure 3). Although there are many statements that R&D’s proximity to headquarters is widely regarded as an important consideration, its location relationships with production plants should not be ignored. Akimoto (1989) believes that R&D location patterns are closely related to production models; many R&D institutions are in fact originally separated from plants. When the enterprise has only one R&D institution, R&D mainly aims to develop short-term technology and products. When a company has more than one plant, R&D institutions are likely to split from production plants and then launch cooperative research on middle-term products. Large-scale enterprises with more than one R&D institution tend to launch R&D activities in different departments, and their R&D institutions easily break away from other departments, become independent institutes or companies and develop new products and technology over time.

Similar to multinational R&D organizations that evolve from centralized to consolidated structures, enterprise R&D institutions within countries are also undergoing organizational change from the impact of external and internal factors. Moreover, location relationships
between R&D institutions and other organizations are in a state of flux, with each type showing spatial differences (Figure 3). Li (2012) examines the locations of enterprise R&D institutions and divides them into four types according to their location relationships with other organizations. According to her findings, enterprises pay great attention to the need for all of their organizations to cooperate when establishing R&D institutions. Generally, R&D, headquarters, production plants and other departments are originally established at the same location (H+P+R type). Influenced by location factors and enterprise strategies, enterprise organizations start experiencing spatial separation; thus, R&D faces diverse location relationships with other organizations. Some R&D institutions are located at the same site as headquarters (H+R type); some are established in production plants (P+R type), others are separated from other departments and located independently as departments or independent companies (R type). Furthermore, distinct industrial location differences occur among the four types.

Figure 3. Location factors and differences of enterprise R&D institutions

Source: Compiled by author.

5. Concluding Remarks

Summarizing the literature on R&D activities, this paper confirms that R&D activities play an important role in regional growth and innovation capacity of enterprises. Although R&D can...
improve productivity, location still matters. Product cycle, geographic proximity, cluster (including rivalry), diversity of proximate industries, and social interactions have great impacts on the location of R&D. Positive externalities from R&D are realized only when knowledge commercialization and retention factors are also present in the region. This means that locations that combine all the above factors will attract more R&D.

Large local market, fully developed infrastructure, favorable policies, a high level of technology and R&D talent in the host country are generally considered important for multi-national R&D. Moreover, MNCs’ R&D organizations have evolved from centralized to consolidated structures under the influence of firm strategies, R&D functions, the stage of product cycle, and the environment. However, previous studies, in fact, lay more emphasis on the generality of MNCs’ R&D organization, but largely neglect the diversities of regions and enterprises.

Meanwhile, R&D performed at home is significantly more productive than that undertaken abroad. Therefore, location factors of national or local enterprise R&D should be increasingly considered. Domestic enterprises and MNCs present different preferences while deciding R&D location. The location of national enterprise R&D is based on intra-firm and inter-firm linkages, social connection, the image of the places, and other factors—these are the elements of social capital.

This paper also presents the location types of R&D institutions. R&D’s location and relocation are decided by the enterprise’s strategies, the R&D function, and the production model. With the growth and transformation of the enterprise, R&D location relationships with other organizations also change from the impact of external and internal location factors. We hope this review will stimulate discussion on R&D activities and lead to further studies based on enterprise perspectives and geographic considerations.

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Literature Review on the Geography of R&D Activities

Li Nana

Abstract: It has been widely confirmed that industrial R&D activities foster regional growth. Numerous researchers including regional scientists, economic geographers, and policy analysts have recently intensified their efforts to uncover the underlying determinants of its geographic distribution. Therefore, this paper reviews and summarizes the important ideas and arguments of recent theories regarding R&D activities to provide basis for a critical examination of the following four aspects: (i) R&D activity and regional growth; (ii) proximity, cluster, product cycle, and knowledge spillovers; (iii) R&D organization and its location determinants of multinational corporations (MNCs); and (iv) location factors and location patterns of enterprises on a national scale.

Through different discussions, it was found that although R&D activity can strengthen innovation capacity and foster regional growth, externality can only be realized when the region where R&D is conducted includes various location factors. Moreover, although MNCs’ R&D contributes significantly to technology transfer, knowledge spillovers from MNCs to the host country are extremely limited. Thus, enterprise R&D activity on a domestic scale should attract more attention. There are some similarities in R&D location on both global and national scales, such as high-level technology, abundant talent, and policies. Furthermore, similar to multinational R&D organization changes from centralized-structures to integrated-networks, the historical evolution of enterprises’ R&D organization and location patterns within the country occurs. Meanwhile, the concept of social capital provides a good explanation for the social linkages between R&D projects and industries. Within this context and from the perspective of enterprise, this paper calls for additional study regarding R&D activities on both regional and local scales.

Key-words: R&D activities, enterprise R&D institutions, multinational R&D, location factors, location types