Agglomeration Economies, Technological Capability, and Firm Location Decision

Yuri Jo (Corresponding author)

Graduate School of Management
KAIST (Korean Advanced Institute of Science and Technology)
207-43 Cheongryangri-Dong, Dongdaemun-Gu
Seoul, Korea, 130-722
E-mail: blackjo@business.kaist.ac.kr
Tel : +82-2-958-3361

Chang-Yang Lee

Graduate School of Management
KAIST (Korean Advanced Institute of Science and Technology)
207-43 Cheongryangri-Dong, Dongdaemun-Gu
Seoul, Korea, 130-722
E-mail: drcylee@business.kaist.ac.kr
Tel : +82-2-958-3061

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Abstract

We show that the effect of agglomeration economies on firm location depends on each firm's technological capability, which is defined as a firm ability to produce new technology and to absorb external knowledge, because technological capability influences the degree of knowledge spillovers between agglomerating firms. Firms having a high level of technological capability enjoy great incoming spillovers as well as are damaged by outgoing spillovers in agglomeration. They avoid clustering in a region crowded by competitors (i.e., competition-level specialization) in order to prevent their proprietary knowledge from leaking out while they prefer to locate in a region specialized with related industries (i.e., complement-level specialization) or in a region with diversified industries or a large number of R&D institutions (i.e., urbanization) in order to absorb useful information from them. On the contrary, firms having a low level of technological capability are more likely to move close to competitors from which they can easily receive incoming knowledge spillovers and have relatively less weight on agglomeration of technologically distant firms in deciding their location since they cannot assimilate less directly applicable or more academic knowledge. Therefore, firm technological capability moderates the relationship between agglomeration economies and firm location. It is also found that this moderating role of technological capability is more strongly present under higher technological opportunity or under higher appropriability condition.

Keywords: Technological capability, specialization externalities, urbanization externalities, technological opportunity, appropriability condition

JEL classifications: O30, M13, R30

1. INTRODUCTION

Firm location has been a subject of great interest for economic researchers as well as regional policy makers because the increased number of firms is seen as necessary for regional economic growth. Many factors influencing firm location have been revealed in a large number of studies (e.g., Carlton, 1983; Hansen, 1987; Woodward et al., 2006; Figueiredo et al., 2002). Among them, agglomeration economies are regarded as one of crucial factors for firm location decision. Researchers proposed agglomeration effects in the form of both pecuniary and technological externalities to explain industry localization and argued that agglomeration in each region further attracts new entrants in a self-reinforcing manner until agglomeration induces congestion effect. Two types of agglomeration economies are specialization externalities which occur in agglomeration of firms in the same industry, and urbanization externalities which occur in agglomeration of diversified industries. It is found that both types of agglomeration economies positively affect firm location decision (e.g., Head et al., 1995; Woodward et al., 2006; Figueiredo et al., 2002).

However, previous studies implicitly assumed that the extent to which agglomeration economies affect firm location is constant across all firms. Although some studies showed that firm size conditions agglomeration effects on firm performance (e.g., Kelly and Helper, 1999;

Harrison et al., 1996; Figueiredo et al., 2002; Shaver and Flyer, 2000; Carod and Antolín, 2004), most studies have ignored that firms are not identical. As Shaver and Flyer (2000) pointed out, if firms are heterogeneous they will differ in the net benefits they receive from agglomerating. Idiosyncratic technological capability is worthy considering on this issue because it affects the degree of knowledge spillovers each firm faces, which is one of primary sources of agglomeration economies.

The difference in firms' ability to generate new technology and to absorb external knowledge - what we call *technological capability* – can influence the relationship between agglomeration externalities and firm performance. There are two kinds of knowledge spillovers, i.e., incoming spillovers or beneficial spillovers and outgoing spillovers or harmful spillovers (Belderbos et al., 2004; Cassiman and Veugelers, 2002). Firms not only benefit from incoming spillovers but also are damaged by outgoing spillovers in agglomeration. A high level of technological capability enables a firm to exploit external knowledge effectively and enjoy great incoming spillovers (Cohen and Levinthal, 1989), while it also makes a firm contribute to the externalities by providing the outgoing spillovers of their new technologies into the regional knowledge pool from which neighboring firms benefit. The net amount of spillovers depends on how firm technological capability affects the degree of each kind of spillovers. Therefore, we need to explore the role of technological capability on knowledge spillovers between agglomerating firms.

Furthermore, industrial characteristics affecting industry technological environments also should be considered in the scrutiny of agglomeration externalities. While firm technological capability affect firm-specific knowledge spillovers, these industrial features determine industry-level spillover condition and can explain the difference in firm location behavior across industries in terms of knowledge spillovers. Two characteristics will be used: technological opportunity representing the speed of technological progress and the likelihood of innovating and appropability condition representing the degree of appropriating the return from innovation.

In this paper, we analyze the impact of firm technological capability and two industrial technological characteristics (i.e., technological opportunity and appropriability condition) on firm location choice in the presence of agglomeration economies. We use a conditional logit model with Korean manufacturing firms data. Section 2 briefly reviews previous literature on agglomeration economies and derives hypotheses on firm location behavior with respect to technological capability and industrial technological characteristics. Section 3 introduces data, variables, and specifications for empirical tests, results of which are presented and discussed in Section 4. Section 5 concludes the paper.

2. LITERATURE AND HYPOTHESES

2.1 Agglomeration economies and technological capability

There are two types of externalities dealing with the role of regional information accumulations on current productivity and hence growth. Externalities may be specialization economies, which derive from a buildup of knowledge associated with communications among local firms in the same industry, or urbanization economies, which derive from a buildup of knowledge or ideas associated with historical diversity (Glaeser et al., 1992). In the view of specialization externality which concerns knowledge spillovers between firms in an industry, industries cluster geographically to absorb the knowledge spilling over between firms and regionally specialized industries grow faster because neighboring firms can learn from each other much better than geographically isolated firms (Acs et al. 2002). A different position posed by Jacobs (1969) views information spillovers between industries to be more important for the firm than within-industry information flows. Urbanization or diversity is seen as the most important regional growth factor, so Jacobs theory predicts that industries located in an area that are highly industrially diversified should grow faster.

Agglomeration economies, from either specialization or urbanization, have been considered to positively affect firm performance and, hence their location decision. Hansen (1987) studied the location choice of firms in São Paulo using nested logit model and found that specialization economies measured by local employment is the most important factor for firm location decision in traditional sectors and urbanization economies measured by the number of skilled workers appear to be significantly important for modern sectors. Head et al. (1995) and Shaver and Flyer (2000) found that industry-level agglomeration economies, i.e., specialization externalities, positively affect the location decision of foreign greenfield investments in the United States. Figueiredo et al. (2002), Cohen and Paul (2005), and Woodward et al. (2006) also confirmed the positive impact of agglomeration economies on location choice.

However, previous studies simplified that every firm, irrespectively of its technological capability,[1] enjoys the externalities with the same intensity. Although knowledge externalities in agglomeration may favor regional economic growth, it is questionable that those externalities

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[1] In this study, technological capability represents a firm ability to generate new technology and to absorb external knowledge. This is a broad concept similar to ‘technological capability’ in Hobday and Rush (2007) or to ‘dynamic capability’ in Teece (2007) and includes ‘technological competence’ (Lee, 2003a), ‘innovativeness’ (Ceccagnoli, 2005), and ‘absorptive capacity’ (Cohen and Levinthal, 1989). Research has consistently shown that firms differ widely in their technological capabilities.

would truly enhance an individual firm's profitability. For a firm, there are two types of knowledge spillovers: incoming spillovers or beneficial spillovers and outgoing spillovers or harmful spillovers. Incoming spillovers refer to the inflow of external knowledge from other firms and R&D institutions, while outgoing spillovers the leakage of proprietary knowledge to other firms (Belderbos et al., 2004). A firm in agglomeration could benefit from incoming spillovers and also could be damaged by outgoing knowledge spillovers. The degree of each kind of spillovers is not constant across all firms and influenced by firm technological capability. There are two possible ways of technological capability to affect knowledge flows between firms.

One way with which firm technological capability affects knowledge spillovers is that it works as a good catalyst in absorbing the incoming spillovers from external knowledge. Following the seminal work of Cohen and Levinthal (1989) on absorptive capacity, Muscio (2007) showed that absorptive capacity helps a firm benefit from incoming spillovers in R&D collaboration and Cassiman and Veugelers (2000) and Arbussà and Coenders (2007) also stressed that the ability to scan and absorb external technology influence firm innovation activities. Specifically, technological capability is more important when a firm absorb technologically distant knowledge which is less directly applicable and more scientific (Cohen and Levinthal, 1989). Although the degree of incoming spillovers decline with the technological distance between firms as shown by Jaffe (1986), firms having a higher level of technological capability can more effectively utilize the incoming spillovers from technologically distant firms. Figure 1a illustrates this concept of the degree of incoming knowledge spillovers with respect to technological distance between firms. The solid line indicates a case of firms having a high level of technological capability and the dotted line indicates a case of firms having a low level of technological capability. When the technological distance between agglomerating firms is zero, that is, firms have perfectly same technological features, the degree of incoming spillovers is greatest and there is no difference between highly capable and low capable firms. However, the slope of the line, which represents the intensity of decline of incoming spillovers with technological distance, is flatter for firms with high technological capability because they are still able to sense and absorb distant knowledge.

The other way with which firm technological capability affects knowledge spillovers is that a highly capable firm tends to contribute to the regional knowledge pool and to be more damaged by outgoing spillovers. Beaudry and Breschi (2003) showed that whereas location in a cluster densely populated by other innovative firms positively affects the likelihood of innovating, quite strong disadvantages exist with the presence of non-innovating firms. They showed an evidence that positive agglomeration externalities are likely to flow only from innovative firms. Also, Shaver and Flyer (2000) found that large establishments which contribute to agglomeration externalities are more damaged by agglomeration and are significantly less likely to agglomerate in their location decision. Figure 1b presents the diagram of the degree of outgoing spillovers. The degree of outgoing spillovers is always larger for firms with high technological capability since they have more knowledge to leak out at every level of technological distance.

In a sum, Figure 1c depicts the net amount of spillovers which is the difference between incoming spillovers (Figure 1a) and outgoing spillovers (Figure 1b). When a firm has a low technological capability, it enjoys greater spillover effect from technologically proximate firms from which it can easily absorb helpful information. When a firm has a high technological capability, however, the loss from outgoing spillovers is substantial and offset the benefit of incoming spillovers. Using its high technological capability, the firm can obtain the net benefit of spillovers only when clustering firms are technologically distant. From this point of view, it can be expected that firms with lower technological capability are more likely to locate in a region with agglomeration of firms in the same industry, which are technologically proximate to them, while firms with higher technological capability are more likely to locate in a region with agglomeration of firms from technologically more distant and diverse industries.

[Place Figure 1 approximately here]

Previous studies, however, have not explicitly considered technological proximity (or technological distance) between agglomerating firms. From the definitions, urbanization externalities obviously come from technologically more distant firms than the case of specialization externalities. The problem is, however, in measuring the degree of specialization because 'a same industry' in the definition of specialization is ambiguous. Although Griliches (1992) pointed out that Standard Industrial Code (SIC), which is a widely used industry classification methods, also expresses technological proximity,[2] researchers used the different levels of the code from two-digit level (e.g., Glaeser et al., 1992) to four-digit level (e.g., Audretsch and Feldman, 1996) in measuring specialization externalities. The number of firms in SIC four-digit level reflects a different level of technological proximity between firms and, hence a different type of specialization, from that in SIC two-digit level. Thus, one type of specialization is insufficient to represent technological proximity.

Accordingly, in order to capture technological proximity between agglomerating firms, we distinguish specialization into two levels: competition-level specialization and complement-level specialization. Competition-level specialization represents the degree of agglomeration of firms of which technological proximity is very close (i.e., they involve in a direct market

[2] Technological proximity between firms is closer when they produce more similar products and belong to a lower level of SIC code.

competition), while complement-level specialization represents the degree of agglomeration of firms where technological proximity is more distant than competition-level but their technological features are interrelated (i.e., firms possess complementary technologies). Urbanization externalities can be seen as derived from agglomeration of firms from far more distant industries than any of the two types of specialization.

Then, the three types of agglomeration, competition-level specialization, complement-level specialization, and urbanization, can reflect the different levels of technological proximity of clustering firms and, as demonstrated by Figure 1, technological capability moderates the relationship between each type of agglomeration externalities and firm location decision. The following hypotheses reflect the moderating role of technological capability.

Hypothesis 1 (Competition-level specialization and technological capability)

Firms having a high level of technological capability are less likely to locate in a region with high competition-level specialization than firms having a low level of technological capability.

Hypothesis 2 (Complement-level specialization and technological capability)

Firms having a high level of technological capability are more likely to locate in a region with high complement-level specialization than firms having a low level of technological capability.

Hypothesis 3 (Urbanization and technological capability)

Firms having a high level of technological capability are more likely to locate in a region with high urbanization than firms having a low level of technological capability.

2.2 Industrial technological characteristics

In this subsection, we consider the effect of industrial technological characteristics. To represent industrial technological characteristics, we use technological opportunities and appropriability conditions. These two industrial features are fundamental determinants of firm R&D behavior (Cohen and Levin, 1989; Levin et al., 1987; Klevorick et al., 1995; Sherer, 1965, 1967) and are used to classify industrial technological regimes (Breshi et al., 2000).

Technological opportunity represents the speed of technological progress, the likelihood of innovating for any given investment, and the ease of making a market opportunity from a new innovation. In higher technological opportunities, technical advance is faster and there are more chances to earn profit from new technology. It does not take a long time for a new innovation to replace an old one in a market. Many firms enter the market in order to introduce their own innovation or to make a profit by imitating other firms' technologies.

Accordingly, firms have a strong incentive to monitor the process and results of other firms' R&D under high technological opportunity. Audretch and Feldman (1996) showed that geographical clustering is more often discovered in these innovative industries where incoming knowledge spillovers play a decisive role in firm R&D behavior. However, as explained in the previous subsection, firms also can be more anxious of outgoing spillovers of their proprietary knowledge because the loss from outgoing spillovers could outweigh the gain from incoming spillovers. Therefore, in higher technological opportunity, firms are more sensitive to incoming spillovers as well as to outgoing spillovers in agglomeration and knowledge spillovers caused by geographical proximity are more strongly related to firm location decision. Thus, we predict that the moderating role of technological capability described in the Hypotheses 1, 2 and 3 will be stronger under higher technological opportunity.

Hypothesis 4 (Technological opportunities)

In industries with high technological opportunities, firms having a high level of technological capability are less likely to locate in a region with high competition-level specialization while they are more likely to locate in a region with high complement-level specialization or with high urbanization than firms having a low level of technological capability. This tendency is weak under low technological opportunities.

Appropriability condition represents how much a firm can appropriate the return from its own innovation and it closely relates to the degree of knowledge spillovers. The higher appropriability condition is, the lower the degree of industry-wide knowledge spillovers is. Under a high level of industry-wide spillovers, an incentive for R&D can be reduced due to less appropriation of private return from innovation (Spence, 1984) and an incentive for imitation can be increased (Ceccagnoli, 2005). Although there is a legal patent system to protect intellectual property rights, it is not equally effective across industries in many reasons, for examples, because scientific knowledge cannot be patented or because propensity to patent differs across industries. In some instances legal protection is effective for appropriating innovation, while in other instances strategic measures, such as secrecy, complex design, and learning curve advantages, are more useful (Mansfield, 1986; Levin et al., 1987). So the appropriability condition of an industry is determined by the nature of technology, by government policies for intellectual property rights, and by firm strategic efforts.

Clustering is one of firm's strategic efforts to increase the degree of spillover by locating near to other firms. Since the degree of industry-wide knowledge spillovers is lower under higher appropriability condition, firms are more willing to geographically cluster to increase the degree of incoming spillovers. In this context, geographical proximity can be used as an appropability-mitigating device. Firms with high technological capability, however, avoid locating closer to competitors because neighboring with competitors enhances outgoing spillovers as well as incoming spillovers and destroys well-established appropriability condition. When appropriability condition is already weak and technological knowledge is easily transmitted without any other strategic efforts, firms' interest in clustering is not strong. Therefore we predict that the moderating role of technological capability described in the Hypotheses 1, 2 and 3 will be stronger under industries with higher appropriability condition.

Hypothesis 5 (Appropriability condition)

In industries with high appropriability condition, firms having a high level of technological capability are less likely to locate in a region with high competition-level specialization while they are more likely to locate in a region with high complement-level specialization or with high urbanization than firms having a low level of technological capability. This tendency is weak under low appropriability condition.

3. DATA , VARIABLES AND SPECIFICATIONS

3.1 Data and variables

Two datasets are used in this study. One set of data contains technological information on new entrants and the other contains information on regional specific economic variables.

The first set of data is the Korean Innovation Survey (KIS) administered by the Science and Technology Policy Institute in Korea in 2002.[3] The dataset includes the various technological information of manufacturing firms' innovation process during 2000-2001. We use data of the firms established during 1999-2000, which are supposed to be new entrants at the time of the survey. There are 352 entrants in the data.[4]

Our geographical unit of analysis is a province and there are 16 provinces in Korea: one capitol city, Seoul, and six largest cities (*Gwangyeok-Si* in the Korean term of administrative districts), Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan, and nine provinces (*Do* in the Korean term of administrative districts), Gyeonggi, Gangwon, Chungcheongbuk,

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[3] The Korean Innovation Survey depends on the Oslo manual of OECD which provides a base for definitions and survey methodology for the Community Innovation Survey. The Community Innovation Survey is a European-wide firm-level survey focusing on innovation and R&D and its questionnaire has a set of common core questions for all countries. The survey data have been widely used for analyzing firms' innovative activities in many countries.

[4] It is not easy to confirm that our data can represent the full entries during the period because there is no information about entire population. Instead, we compared our data to the data of firms which entered during the same period and survived until 2007 in KIS-VALUE database which is supported by Korea Information Service, Inc. and provides financial and accounting information of registered firms. Our dataset is an acceptable sample to represent the sample dataset of KIS-VALUE.

Chungcheongnam, Jeollabuk, Jeollanam, Gyeongsangbuk, Gyeongsangnam, and Jeju. Because the total size of Korea is 99,538km^2, which is similar to the small European countries, Hungary (93,030 km^2) or Portugal (92,391km^2), or to the small US states such as Kentucky (104,664km^2) or Indiana (94,327km^2), our spatial unit of analysis is quite local.[5] Figure 2 illustrates firm location in our sample.

[Place Figure 2 approximately here]

To represent the key independent variable, firm technological capability, we use the question in the KIS data asking 'did your firm introduce technologically new products or services onto the market during 2000-2001?'. *Technological capability* (**TC**), is constructed to be 1 (high capability) if an entrant answered yes to the question or 0 (low capability) otherwise. It is supposed that an entrant has a high level of technological capability if it introduces technologically new products onto the market in a short time after its entry.

Table 1 shows technological capability of entrants in each location in the sample. There are 99 highly capable entrants which are about 28% of all entrants. Gyeonggi is the most attractive

[5] Most authors agree that geographical area of analysis should be local, since various applied studies have argued that the states, in the case of America, and the regions, in the case of Europe, are too large to be considered as suitable units of analysis (Viladecans-Marsal, 2004; Audretsch and Feldman, 1996).

region for entrants since 30% of all entrants and 41% of highly capable entrants chose there to locate. Seoul, the capitol city, is the second attractive region. In fact, Seoul and Gyeonggi are the largest manufacturing provinces in Korea, where about 40% of GDP is realized and their population reaches to a half of total Korean population. After the Korean War, Korean economy grew fast with average 6.9% yearly growth rate (Bank of Korea, 2005) primarily in manufacturing base which, in spatial term, has been centered on the metropolitan area of Seoul and its proximate regions. During the period, however, other suburban regions have fostered heavy manufacturing or motor vehicle industries and central governments intentionally have incited firms to locate or relocate outside metropolitan areas. Economic activities have become more decentralized in recent years. Hence, similarly to the historical pattern, about a half of entrants in our dataset select their location in concentrated areas, Seoul and Gyeonggi, and the other half locate in other large cities and suburban areas. Jeju, which is an island with its main industry being tourism, has no entrants in our sample.

[Place Table 1 approximately here]

Variables representing industrial technological opportunity and appropriability condition are also constructed from the KIS data. For technological opportunity, following Lee (2003b), we use the question ‘where your new or improved product stands in its product life cycle?’ We give 4, 3, 2, and 1 point to introductory, growing, mature, and declining stage respectively. We construct *technological opportunity of an industry* (**TO**) with 1 (high) if the industry average of the answers to the question is greater than the median value across all industries and 0 (low) otherwise. Each industry is at Korean SIC two-digit level.[6]

Appropriability condition is calculated from the firm answers which evaluate the importance of four appropriation methods to protect internal knowledge or innovation, patent registration, secrecy, complex design, and market preoccupancy, in a six-point scale from 0 (not relevant) to 5 (very important). We construct *appropriability of an industry* (**APP**) with 1 (high) if the industry average of the answers is greater than the median value across all industries and 0 (low) otherwise.

We summarize technological opportunity, appropriability condition, and the number of entrants of each industry in Table 2. Industries with high technological opportunities are food and beverage (15), chemicals (24), rubber and plastic (25), non-metallic mineral products (26), fabricated metal products (28), other machinery and equipments (29), semiconductor and other electronic components (32), medical and optical instruments (33), motor vehicles (34), and other transport equipments (35). About 80% of entrants (282 of 352) entered into these high **TO**

[6] The level of industry is aggregate because the number of firms in the KIS data which answered the question is limited.

industries and the greatest number of entries (84 of 352) occurred in the industry of semiconductor and other electronic components. It is a general phenomenon that firm entries occur intensively in industries with high technological opportunities (Geroski, 1995).[7]

[Place Table 2 approximately here]

Industries with high appropriability condition are textiles (17), publishing (22), petroleum products and nuclear fuel (23), chemicals (24), non-metallic mineral products (26), basic metals (27), fabricated metal products (28), electrical machinery (31), medical and optical instruments (33), and furniture (36). We can see that there are more entries in low appropriability condition (66% of all entrants) than in high appropriability condition (34% of all entrants). From a Chi-square test, we confirmed that two industrial variables, **TO** and **APP**, are not systematically correlated.

The second set of data is collected from Mining and Manufacturing Survey (MMS) in 1998 by Korea National Statistical Office. The dataset contains information on regional specific economic variables. As proposed in the previous section, we construct specialization variables

[7] Also, this phenomenon is partially caused by the Korean governments' favorable policies towards information technology sectors. Among various policies to overcome the financial crisis in 1997, Korean government encouraged firms to enter into information, network, and telecommunication areas.

in two levels in order to differentiate technological proximity. One is the competition-level specialization represented by the number of firms in SIC three-digit level industry within each area (**WTHN_CMPT**) and in neighboring areas (**NGHB_CMPT**). We include neighboring areas in order to check out not only localization of knowledge spillovers but the effect of neighboring specialization externalities because our geographical unit of analysis is local. The other is the complement-level specialization, which is the number of firms in SIC two-digit level industry within each area (**WTHN_CMPL**) and in neighboring areas (**NGHB_CMPL**). We construct the complement-level specialization by subtracting the number of firms in three-digit level from the number of firms in two-digit level industry because the former is nested in the latter and is used as representing the competition-level specialization.

For urbanization variables, we use Herfindah-Hirshman index (HHI) of the number of firms in two-digit level across all manufacturing industries and **POPULATION** in each area in 1998. Since HHI decreases with the diversity, we construct the variable **DIVERSITY** by subtracting the HHI value from one. While **POPULATION** indicates the overall size and infrastructure of an area, **DIVERSITY** represents the composition of manufacturing structure. We also include the number of universities and public R&D institutions per millions of population (**RND_ORG**) and Gross Regional Product per capita (**GRP**). They reflect the extent to which diversified knowledge can be actively generated and commercialized in each area. Descriptive statistics of independent regional variables are presented in Table 3.

[Place Table 3 approximately here]

3.2 Econometric specifications

We use conditional logit specifications to model firm location decision. Suppose that the restricted profit function, π_{ij}, of the entrant *i* in the location *j* ($1 \leq j \leq J$) is,

$$\pi_{ij} = z'_{ij}\beta + \varepsilon_{ij},$$

where z_{ij} are various factors affecting the profit, β is their coefficient vector, and ε_{ij} is the entrant-location specific error term. We further assume that ε_{ij} is independently distributed across *i* and *j* and that ε_{ij} follows the Weibull distribution (i.e., the cumulative distribution function is exp-(exp(-ε_{ij}))). McFadden (1974) has shown that the probability that the entrant *i* locates in the location *j* is

$$\Pr(Y_i = j \mid z_i) = \frac{\exp(z'_{ij}\beta)}{\sum_{k=1}^{J}\exp(z'_{ik}\beta)},$$

which can be estimated by maximum likelihood estimation.[8]

[8] This McFadden's choice model and individual firm data are useful to investigate a firm's incentive to locate in a specific region in a dynamic perspective. Studies at industry level do not capture each firm's location behavior

In analyzing the effect of specialization variables on the location choice, regional fixed effects are included in our estimation to control for the possibility that regional differences in labor costs, government incentives, or other attributes affect the expected profitability of locating within each area. As Bartik (1985) pointed out, this kind of specification is mathematically same to a nested conditional logit model and is useful to analyze firm location choice when it is unclear that alternative regions are sufficiently different to each other. Then, the profit function of the entrant *i* in the location *j* is presented like following:

$$\pi_{ij} = \alpha_j + \beta \text{Specialization}_{ij} + \gamma \text{TC}_i + \delta(\text{TC}_i \times \text{Specialization}_{ij}) + \varepsilon_{ij}, \qquad (1)$$

where α_j is a regional fixed constant and $\text{Specialization}_{ij}$ is a vector of four specialization variables (**WTHN_CMPT**, **NGHB_CMPT**, **WTHN_CMPL**, **NGHB_CMPL**). The coefficient β represents the effect of specialization variables on the expected profit, hence on the location choice, of all entrants, while δ represents the additional effect of specialization variables in the case of highly capable firms. The coefficient δ will uncover how technological capability alters the impact of specialization externalities on location decision, which is one of main purposes in this study. The coefficient γ captures the effect of technological capability on the

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because industrial data contains only aggregated information about entry and exit.

profit and will not be estimated because it is common in all areas.

The second specification includes urbanization variables as well as specialization variables. Because our urbanization variables are regional-specific, regional fixed constants are dropped in this specification. Then, the profit function of the entrant *i* in the location *j* is

$$\pi_{ij} = \beta \text{Specialization}_{ij} + \gamma \text{TC}_i + \delta(\text{TC}_i \times \text{Specialization}_{ij})$$
$$+\sigma \text{Urbanization}_j + \mu(\text{TC}_i \times \text{Urbanization}_j) + \varepsilon_{ij}, \quad (2)$$

where Urbanization_j is a vector of urbanization variables (**POPULATION**, **DIVERSITY**, **RND_ORG**, **GRP**). The coefficient μ will capture the role of technological capability on the relationship between urbanization and location choice. Conditional logit models based on the specifications (1) and (2) will be estimated using the pooled data and grouped data by industrial characteristics.

4. RESULTS AND DISCUSSIONS

In a conditional logit model, the independence assumption of ε_{ij} leads to the

‘Independence of Irrelevant Alternatives’ (IIA) property (McFadden, 1974). It means that adding or deleting alternatives does not affect the odds among the remaining alternatives. In this study, we performed the specification test presented by Hausman and McFadden (1984) to test IIA. This test compares the estimated coefficients from the full model to those from a restricted model that excludes at least one of the alternatives. We ran the test by excluding each area from the choice set for all specifications that we present. The tests did not reject the null hypotheses more than could be attributable to chance. Therefore, our model appears robust to the IIA assumption.

4.1 Agglomeration economies and technological capability

Table 4 presents the estimation results of specifications (1) and (2) for the pooled data of 352 firms. While Models (A) and (C) estimate the coefficients of agglomeration variables without the interactive effect of technological capability, Model (B) includes the interaction terms between specialization variables and technological capability following the specification (1) and Model (D) covers the interaction terms between all agglomeration variables and technological capability following the specification (2).

We confirm the positive agglomeration economies on firm location choice in Models (A) and (C) which do not include technological capability. Both the competition-level and complement-level specializations (**WTHN_CMPT** and **WTHN_CMPL**) are found to have significantly positive effects on the location choice. It confirms the existence of specialization externalities in both levels. While the complement-specialization in neighboring areas (**NGHB_CMPL**) also has a positive impact, the coefficient is smaller than that within the area, which implies that those externalities are localized in a certain distance.[9] In Model (C), urbanization variables, **POPULATION** and **DIVERSITY**, also have positive influences on location choice. A firm prefers to locate in an urbanized region with good infrastructures, large market demands and diversified industry composition. Therefore, if we do not consider firm technological capability, agglomeration economies, in general, positively affect firm location decision.

[Place Table 4 approximately here]

When we include technological capability, however, the effect of each kind of

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[9] It is possible a direct comparison between coefficient magnitudes of different specialization variables because all specialization variables have the same unit, i.e., the number of firms. Their coefficients have interpretations as being proportional to the change in the probability that results from a change in the specialization variable. It is from the derivation that if $\mathrm{P}_j = \exp\sum \beta_m x_{ijm} / \sum_{k=1}^{J} \exp\sum \beta_m x_{ikm}$, then $\partial \mathrm{P}_j / \partial x_{ijm} = \beta_m \mathrm{P}_j (1-\mathrm{P}_j)$.

agglomeration significantly differs. First, agglomeration economies do not always work as 'economies' in competition-level specialization. In Model (B), the variable **WTHN_CMPT** has a positive coefficient while its interactive effect with **TC** is significantly negative and offsets its positive effect. It means that firms with low technological capability are more likely to locate in a highly competition-level specialized area while firms with high technological capability tend to avoid locating the area. Everything equal (i.e., all regions are identical), 10% increase in **WTHN_CMPT** at the sample mean in an area leads to 1.06% increase in the location probability of low capability firms in that area but 0.37% decrease in that of high capability firms.[10] Although this value is quite small, it shows that specialization externalities can be negative as well as positive according to firm technological capability. Second, the complement-level specialization within each area (**WTHN_CMPL**) has significantly positive effects for both types of entrants, which says that every firm considers the complement-level specialization as a positive factor in deciding their location. However, the magnitude of the coefficient is larger for high capability firms and only for high capability firms the variable in neighboring areas (**NGHB_CMPL**) also has a significantly positive influence. From the coefficients in Model (B), 10% increase in the number of firms in this level at the sample mean in an area or in neighboring areas gives rise to 3.71% or 9.68% increase of the expected location probability of

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[10] The elasticity of the probability with respect to the variable *x* is given by $\partial \ln P_j / \partial \ln x_{ijm} = (\beta_m + \delta_m I_i) x_{ijm} (1 - P_j)$.

highly capable firms. These are the largest effects among specialization variables. At the same time, firms having a low technological capability have less weight on the complement-level specialization than the complement-level specialization in deciding their location. The effect of **WTHN_CMPL** is about half of that of **WTHN_CMPT** for low capability firms. These results on specialization variables in Model (B) are almost identical in Model (D).

The above results suggest that an entrant differently reacts to specialization externalities according to its technological capability. One the one hand, a low capable firm decides to move close to its technologically proximate competitors from which it can easily receive incoming knowledge spillovers. It does not worry about outgoing spillovers to competitors because it has less proprietary knowledge to leak out. A technologically capable firm, on the other hand, tends to avoid locating in the region crowded by competitors in order to prevent their knowledge from leaking out. For the firm, the loss from outgoing spillovers in agglomeration of technologically proximate firms dominates the benefit of incoming spillovers. Although a highly capable entrant can be damaged from outgoing spillovers in competition-level specialization, it can utilize the incoming spillovers from complement-level specialization more effectively than a low capable firm. Consequently, firms with high technological capability are less likely to locate in a region with high competition-level specialization while they are more likely to locate in a region with high complement-level specialization than firms with low technological capability. Thus, firm technological capability moderates the effect of two kinds of specialization on location choice as explained in Hypotheses 1 and 2.

Finally, for urbanization variables, in Model (D), **POPULATION** and **DIVERSITY** significantly increase the location probability for every firm. There is no significant difference in the magnitudes of their coefficients between two types of entrants. However, it is observed that **RND_ORG** and **GRP** have positive effects on location choice of high capability firms while they have a negative or an insignificant effect on location choice of low capability firms. If all areas are identical, 10% increases in **RND_ORG** and **GRP** at the sample mean result in 3.19% and 9.69% increases in the location probability of high capability firms while 10% increase in **RND_ORG** leads to 4.71% decrease in the location probability of low capability firms. This suggests that only a high capability entrant benefits from those urbanization externalities since a high level technological capability is necessary in absorbing scientific and diversified knowledge which is produced or commercialized by universities, public institutions, and other firms. On the contrary, firms with low technological capability are less likely to locate in an area with more universities and laboratories because they not only cannot utilize scientific knowledge but also cannot afford to pay highly educated employees in the area. So, low capability firms can suffer from the congestion effect from the agglomeration of R&D institutions rather than benefit from the externalities. Because the number of low capability firms is greater than that of high capability firms, **RND_ORG** appears to negatively affect firm location decision in the pooled sample in Model (C). Thus, as shown in Hypothesis 3, technological capability has a conditional effect on urbanization externalities.

4.2 Industrial technological characteristics

Now, we explore the effect of industrial technological characteristics. First, Table 5 presents the estimation results of specifications (1) and (2) for two separated groups by technological opportunity. Low **TO** group is an industry group of which technological opportunity is equal to 0 while high **TO** group is an industry group of which technological opportunity is 1.

[Place Table 5 approximately here]

In the low **TO** group, all interactive terms with **TC** are statistically insignificant. Firm technological capability barely affects the relationship between agglomeration and location behavior. Both types of entrants are more willing to locate in a region with higher specialization in both competition- and complement-levels and with less universities and public institutions.

In the high **TO** group, however, firm technological capability is working as a moderating factor on the effect of agglomeration variables. Low capability firms are more likely to choose to locate in a highly competition-level specialized region while high capability firms are less likely to locate such a region and are more likely to locate in a complement-level specialized region. Also, urbanization variables such as **RND_ORG** and **GRP** are positively related to location decision only for high capability firms.

As we describe in Section 2, under higher technological opportunities where technological progress is faster and monitoring other firms' R&D is more important, firms take the degree of spillovers into more consideration in deciding their location. A firm with high technological capability tries to prevent their proprietary knowledge to leak out to competitors and this incentive to prevent outgoing spillovers makes the firm locate in less specialized area. At the same time, it takes an advantage of its high technological capability to utilize complementary technologies produced by universities or technologically distant industries. Hypothesis 4 on technological opportunity is supported by this result.

Second, Table 6 illustrates firm location behavior depending on appropriability condition. Low **APP** group is an industry group of which appropriability condition is equal to 0 while high **APP** group is an industry group of which appropriability condition is 1.

[Place Table 6 approximately here]

Even though the overall features are similar in both groups, the magnitude of the coefficients of specialization variables tends to be greater in high **APP** group than in low **APP** group. That is, specialization variables and the interaction terms between specialization variables and technological capability have larger and more statistically significant coefficients in high **APP** group. For example, the negative effect of competition-level specialization for high capability firms is significant only in high **APP** group and the magnitude is much larger than in low **APP** group. As described in Hypothesis 5, technological capability conditions the effect of specialization more strongly under high appropriability condition. If industrial appropriability condition is high, geographical proximity can be a firm's strategic method to increase knowledge spillovers. Therefore, firms are more sensitive to agglomeration economies or diseconomies and the moderating role of technological capability is greater.

However, urbanization variables have no noticeable difference between low and high **APP** groups. Firms in both groups are more likely to locate in a more densely populated area as seen in the positive coefficient of **POPULATION**. Also the result on **RND_ORG** and **GRP** is not clear. The variable **TC** conditions the effect of **RND_ORG** in high **APP** group as well as the effect of **GRP** in low **APP** group. Firms in both groups at least partially consider technological capability as a moderating factor on urbanization externalities. One possible reason for this confusing result could be that industrial approprability condition generally prevents other firms' imitation within a specific product area (i.e., within a technologically proximate sector), not across all industrial sectors (i.e., across technologically distant sectors). Since the loss from imitation is great between competing firms, industry policy may focus on appropriability protection from technologically proximate firms. So, firms are able to access information and idea from diversified industries without the aid of geographical proximity even in high appropriability condition. Thus, appropriability condition in our study fails to make the difference in the effect of urbanization externalities between two groups.

5. CONCLUSIONS

In this paper, we have showed that the effects of agglomeration economies on firm location choice significantly differ depending on each firm's technological capability. Technological capability affects the degree of two kinds of knowledge spillover, i.e., incoming spillovers and outgoing spillovers. While a high level of technological capability helps a firm to sense, absorb, and utilize technological knowledge or scientific discoveries from technologically distant and diverse industries, it drives a firm to act as a knowledge provider for the regional knowledge pool and to contribute to agglomeration externalities. The net amount of knowledge spillover, that is, the difference between incoming spillovers and outgoing spillovers, relies on firm technological capability and technological distance between clustering firms. As a result, we hypothesized that firms having a low level of technological capability benefit more from agglomeration of technologically close firms while firms having a high level of technological capability benefit more from agglomeration of technologically distant firms. For these hypotheses, we construct three kinds of agglomeration variables according to technological proximity: competition-level specialization, complement-level specialization, and urbanization.

From the conditional logit models with Korean manufacturing firms data, we have found supportive evidences for our hypotheses. The competition-level specialization has a positive effect on location choice for low capability firms while it has a negative effect for high capability firms. The complement-level specialization has a positive influence for all firms but the magnitude of the effect is larger for high capability firms. Also, urbanization has a larger positive effect on location decision for high capability firms than for low capability firms. So, technological capability moderates the relationship between all kinds of agglomeration and firm location decision.

These differences in location behavior are more strongly present in higher technological opportunity. In high technological opportunity, knowledge spillovers play an essential role in deciding firm location since it is important for a firm to monitor other firms' R&D and to understand new technological discoveries. So, firms are more sensitive to geographical proximity between firms. However, the effect of industrial appropriability condition is relatively unclear. It was expected that the moderating effect of technological capability would be stronger under high appropriability condition because geographical proximity would enhance the degree of spillovers and mitigate appropriability condition. Although the moderating role of technological capability is found on specialization externalities in high approprability condition, urbanization externalities do not have any obvious difference between low and high appropriability conditions. One possible reason is that some instruments to protect innovation, such as learning curve advantages, can be applied in a narrow product market and are not powerful between industries. Firms can easily obtain useful knowledge from diversified industries and do not need an appropriability-mitigating clustering. This argument, however, is still vague and further research is required on this issue.

Our findings emphasize the role of firm and industry heterogeneity on the location choice when two types of knowledge spillovers (i.e., incoming spillovers and outgoing spillovers) are localized. Agglomeration economies caused by knowledge spillovers may be either beneficial or harmful and either large or small according to firm and industry characteristics.

This study is a first step to incorporate the technological characteristic into agglomeration economies on location decision and provide insights regarding a broad range of issues. From a research perspective, to understand the firm location behavior, it is critical to effectively measure the effects of agglomeration economies. While economies of agglomeration prevail in previous literature, we showed that diseconomies of agglomeration apparently work for a certain firm. From a firm strategic perspective, managers should carefully account the effect of agglomeration at the point of selecting the firm location because it benefits from externalities in agglomeration and also make contributions to the externalities. The net benefit from agglomeration differs across firms and industries. From a policy perspective, regional policies supporting agglomeration are not sufficient to stimulate innovation or growth. Our results indicate that innovative entrants tend to avoid clustering and Beaudry and Breshi (2003) also showed that the agglomeration of non-innovative firms decreases the number of innovations. More elaborate policies are required.

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Figure 1. The degrees of knowledge spillovers with technological distance

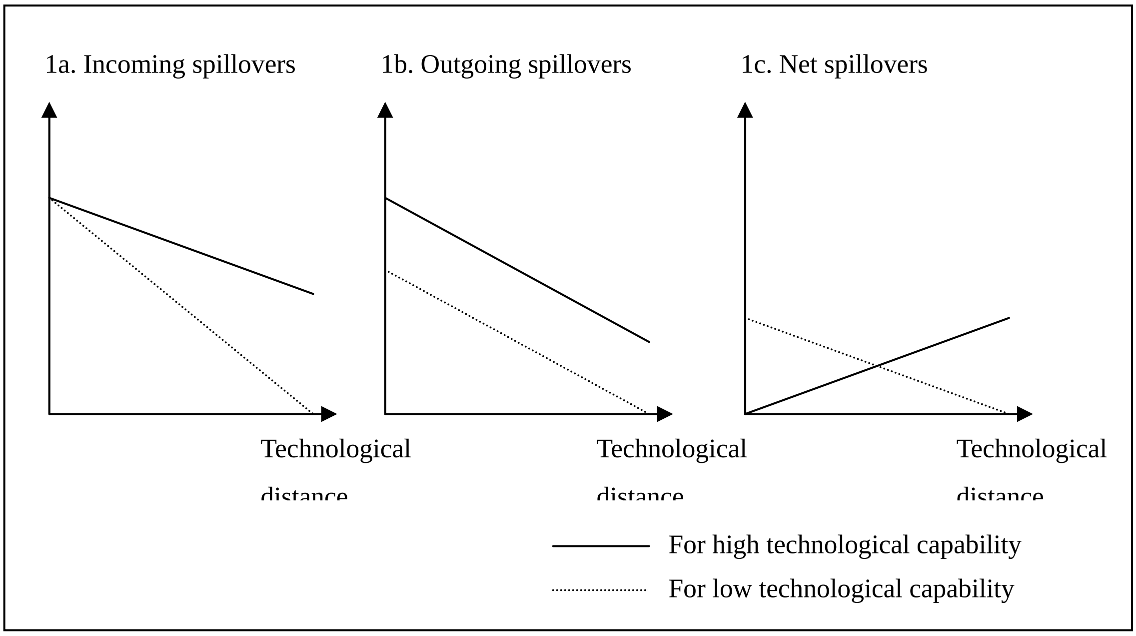

Figure 2. Firm location

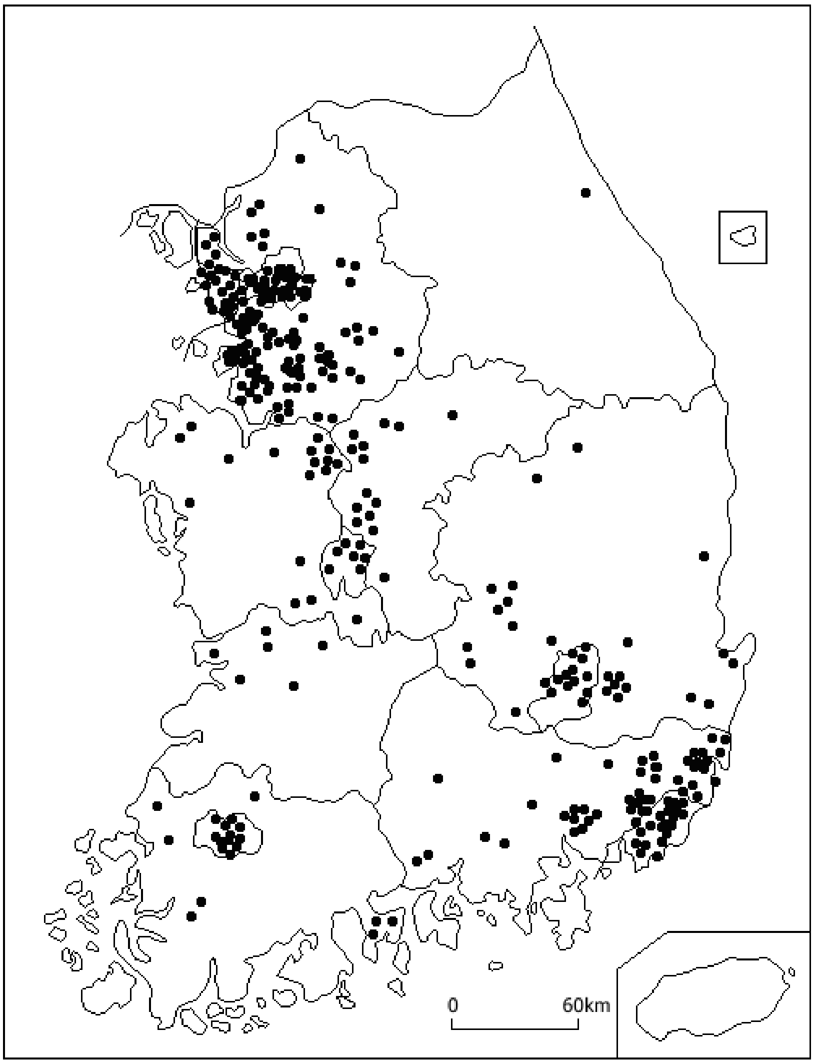

Table 1. Technological capability (TC) of entrants in each province

Provinces	Firms with High TC	Firms with Low TC	Subtotal
Seoul	17	42	59
Busan	3	16	19
Daegu	1	14	14
Incheon	4	15	19
Gwangju	1	11	12
Daejeon	2	4	6
Ulsan	4	11	15
Gyeonggi	41	65	106
Gangwon	0	1	1
Chungcheongbuk	6	8	14
Chungcheongnam	6	12	18
Jeollabuk	1	6	7
Jeollanam	2	6	8
Gyeongsangbuk	4	18	22
Gyeongsangnam	7	24	31
Jeju	0	0	0
Total	99	253	352

Table 2. Industrial technological characteristics and the number of entrants

Industry	TO	APP	Firms with high TC	Firms with low TC	Subtotal
15 Food products and beverages	1	0	1	13	14
17 Textiles (except sewn apparel)	0	1	1	9	10
18 Sewn wearing apparel and fur articles	0	0	0	4	4
19 Tanning and dressing of leather	0	0	0	3	3
20 Wood and products of wood and cork	0	0	2	2	4
21 Pulp, paper and paper products	0	0	1	3	4
22 Publishing, printing and reproduction of recorded media	0	1	0	5	5
23 Coke, refined petroleum products and nuclear fuel	0	1	0	1	1
24 Chemicals and chemical products	1	1	11	17	28
25 Rubber and plastic products	1	0	5	11	16
26 Other non-metallic mineral products	1	1	0	14	14
27 Basic metals	0	1	4	13	17
28 Fabricated metal products (except machinery and furniture)	1	1	6	10	16
29 Other machinery and equipments	1	0	16	39	55
31 Electrical machinery and apparatuses	0	1	4	10	14
32 Semiconductor and other electronic components	1	0	35	49	84
33 Medical, precision and optical instruments, watches and clocks	1	1	3	3	6
34 Motor vehicles, trailers and semitrailers	1	0	6	38	44
35 Other transport equipments	1	0	1	4	5
36 Furniture	0	1	3	5	8
Total			99	253	352

Table 3. Descriptive statistics

Variable	Mean	St. Dev.	Min	Max
WTHN_CMPT [1)]	126.30	249.44	0	4429
NGHB_CMPT [2)]	432.56	508.14	0	4973
WTHN_CMPL [3)]	161.24	300.52	0	2846
NGHB_CMPL [4)]	562.17	658.02	0	3915
POPULATION	2,948,372	2,623,683	534,715	10,321,496
DIVERSITY [5)]	0.8789	0.0482	0.7471	0.9264
RND_ORG [6)]	14.7300	6.9126	4.9113	33.4402
GRP	10,631.38	3,631.35	7,043	23,230

1) the number of firms in the three-digit level industry within each area

2) the number of firms in the three-digit level industry in neighboring areas

3) the number of firms in the two-digit level industry, but not in the three-digit, within each area

4) the number of firms in the two-digit level industry, but not in the three-digit, in neighboring areas

5) 1 - (HHI of the number of firms across all two-digit level industries in each area)

6) the number of universities and public R&D institutions per millions of people in each area

Table 4. Conditional logit estimation for firm location choice for pooled data

	Specification (1)		Specification (2)	
	Model (A)	Model (B)	Model (C)	Model (D)
WTHN_CMPT	0.0007255*** (0.0002015)	0.0009023*** (0.0002332)	0.0006593*** (0.0001926)	0.0008344*** (0.0002263)
NGHB_CMPT	0.0001776 (0.0002315)	0.0003076 (0.0002578)	0.0000680 (0.0002170)	0.0002143 (0.0002426)
WTHN_CMPL	0.0008391*** (0.0002173)	0.0005243** (0.0002341)	0.0007420*** (0.0001930)	0.0004291** (0.0002189)
NGHB_CMPL	0.0005234** (0.0002100)	0.0002784 (0.0002226)	0.0003661** (0.0001805)	0.0001512 (0.0001937)
POPULATION			1.42e-07*** (2.22e-08)	1.27e-07*** (2.55e-08)
DIVERSITY			5.691429*** (1.646792)	4.946430*** (1.838349)
RND_ORG			–0.0209268* (0.0120303)	–0.0341086** (0.0141036)
GRP			0.0000259 (0.0000184)	8.48e-06 (0.000021)
WTHN_CMPT × TC		–0.0012154** (0.0005955)		–0.0012087** (0.0006014)
NGHB_CMPT × TC		–0.0006996 (0.0005450)		–0.0008767 (0.0005616)
WTHN_CMPL × TC		0.0019335*** (0.0005008)		0.0018278*** (0.0005595)
NGHB_CMPL × TC		0.0015592*** (0.0005026)		0.0015003*** (0.0005311)
POPULATION × TC				5.31e-08 (5.44e-08)
DIVERSITY × TC				3.466384 (4.413639)
RND_ORG × TC				0.0571934** (0.0280268)
GRP × TC				0.0000888* (0.0000454)
Regional fixed effects	Included	Included	Not included	Not included
$LR\ \chi^2$	392.61***	418.07***	355.64***	385.63***
Pseudo R^2	0.2011	0.2142	0.1822	0.1976

Standard errors are below estimates in parenthesis.

***, **, * are significantly different than zero at the 0.01, 0.05, and 0.10 confidence levels respectively.

`Table 5. Conditional logit estimation for firm location choice according to technological opportunity

	Low TO group		High TO group	
	Specification (1)	Specification (2)	Specification (1)	Specification (2)
WTHN_CMPT	0.0012213***	0.0011687***	0.0005817*	0.0006266*
	(0.0004257)	(0.0004146)	(0.0003548)	(0.0003415)
NGHB_CMPT	0.0003285	0.0001292	0.0004541	0.0003269
	(0.0005165)	(0.0005006)	(0.0003458)	(0.0003159)
WTHN_CMPL	0.0013279***	0.0010377**	0.0003195	0.0003235
	(0.0004726)	(0.0004484)	(0.0002845)	(0.0002715)
NGHB_CMPL	0.0006434	0.0003680	0.0001567	0.0000341
	(0.0004463)	(0.0003659)	(0.0002657)	(0.0002414)
POPULATION		3.88e-08		1.50e-07***
		(5.93e-08)		(2.85e-08)
DIVERSITY		4.080719		6.173145***
		(3.961603)		(2.261318)
RND_ORG		–0.0960542***		–0.0218447
		(0.0373474)		(0.0154384)
GRP		–0.0000423		0.0000202
		(0.0000453)		(0.0000241)
WTHN_CMPT × TC	0.0004280	0.0006075	–0.0011313*	–0.0011261*
	(0.0019955)	(0.0020445)	(0.0006908)	(0.0007025)
NGHB_CMPT × TC	–0.0017165	–0.0015684	–0.0007701	–0.0009600
	(0.0018413)	(0.0017933)	(0.0006033)	(0.0006286)
WTHN_CMPL × TC	0.0020130	0.0020004	0.0018799***	0.0018794***
	(0.0014220)	(0.0015350)	(0.0005697)	(0.0006351)
NGHB_CMPL × TC	0.0008954	0.0009241	0.0017202***	0.0016942***
	(0.0013624)	(0.0013261)	(0.0005600)	(0.0006007)
POPULATION × TC		–1.19e-08		7.25e-08
		(1.37e-07)		(6.21e-08)
DIVERSITY × TC		–8.267209		4.759461
		(8.823644)		(5.328332)
RND_ORG × TC		–0.0423905		0.0707043**
		(0.1080047)		(0.031076)
GRP × TC		–0.0000297		0.0001215**
		(0.0001257)		(0.0000518)
Regional fixed effects	Included	Not included	Included	Not included
LR χ^2	120.49***	107.87***	327.51***	301.21***
Pseudo R^2	0.3104	0.2779	0.2094	0.1926

Standard errors are below estimates in parenthesis.

***, **, * are significantly different than zero at the 0.01, 0.05, and 0.10 confidence levels respectively.

Table 6. Conditional logit estimation for firm location choice according to appropriability condition

	Low APP group		High APP group	
	Specification (1)	Specification (2)	Specification (1)	Specification (2)
WTHN_CMPT	0.0007441***	0.0007301***	0.0014637***	0.0011236**
	(0.0002444)	(0.0002457)	(0.0005635)	(0.0005410)
NGHB_CMPT	–0.0000458	–0.0000669	0.0013860***	0.0011113**
	(0.0003304)	(0.0003059)	(0.0005326)	(0.0005102)
WTHN_CMPL	0.0004154	0.0004025	0.0009272**	0.0005868
	(0.0002813)	(0.0002606)	(0.0004365)	(0.0004202)
NGHB_CMPL	0.0002931	0.0002039	0.0003746	7.32e-06
	(0.0002736)	(0.0002474)	(0.0004108)	(0.0003358)
POPULATION		1.51e-07***		7.86e-08*
		(3.13e-08)		(4.44e-08)
DIVERSITY		4.965741**		4.649150
		(2.327384)		(3.060346)
RND_ORG		–0.02273775		–0.0548275**
		(0.0170710)		(0.0247942)
GRP		–4.01e-06		0.0000259
		(0.0000292)		(0.0000309)
WTHN_CMPT × TC	–0.0010001	–0.0008711	–0.0017153*	–0.0013352
	(0.0007614)	(0.0007784)	(0.0010369)	(0.0010082)
NGHB_CMPT × TC	–0.0002450	–0.0005464	–0.0028062**	–0.0022436**
	(0.0006717)	(0.0007303)	(0.0011301)	(0.0010914)
WTHN_CMPL × TC	0.0015191**	0.0015946**	0.0033697***	0.0026994**
	(0.0006286)	(0.0006860)	(0.0010339)	(0.0011801)
NGHB_CMPL × TC	0.0016208***	0.0017687***	0.0018707*	0.0013511
	(0.0006195)	(0.0006841)	(0.0010908)	(0.0010613)
POPULATION × TC		4.21e-08		3.28e-08
		(6.69e-08)		(1.04e-07)
DIVERSITY × TC		3.784563		1.652531
		(5.581936)		(7.418232)
RND_ORG × TC		0.0497211		0.0836714*
		(0.0355261)		(0.0454854)
GRP × TC		0.0001434***		–0.0000466
		(0.0000559)		(0.0001087)
Regional fixed effects	Included	Not included	Included	Not included
LR χ^2	288.15***	268.36***	159.06***	134.76***
Pseudo R^2	0.2230	0.2077	0.2410	0.2042

Standard errors are below estimates in parenthesis.

***, **, * are significantly different than zero at the 0.01, 0.05, and 0.10 confidence levels respectively.