Track 3

Technological Complexity and the Restructuring of Subsidiary Knowledge Sourcing in Intra-Multinational and Inter-Firm Networks

John Cantwell
Management and Global Business Department, Rutgers University, Newark, USA, cantwell@business.rutgers.edu
Camilla Noonan
Management Department, University College Dublin, Ireland, camilla.noonan@ucd.ie
Feng Zhang
PhD Program of International Business, Rutgers University, Newark, USA, fengz@andromeda.rutgers.edu

ABSTRACT

This paper focuses on the implications of increasing technology complexity for patterns of knowledge sourcing in the Multinational Corporation (MNC). To better understand the increased capacity of subsidiaries for knowledge sourcing both inter- and intra-organizationally, we examine the influence of technological complexity on knowledge sourcing pattern of foreign-owned subsidiaries in Germany. We focus our study on the pharmaceutical industry, and find that as technological complexity rises, firms tend to increasingly rely on both their international and local inter-organizational networks to facilitate knowledge accumulation, but for different purposes. The international network is used for a more intensive cross-border exploitation of knowledge within a field, while the local external network is used increasingly for the exploration of new knowledge combinations. Finally, our findings contribute to the literature of the restructuring of MNC international knowledge generation networks, as well as open innovation systems.

Key Words: Technological Complexity, Intra- and Inter-organizational Knowledge Accumulation, Strategy

1. INTRODUCTION

From having often been a pure recipient of technologies initially developed by their parent companies with an essentially dependent or locally adaptive role in the early development of the Multinational Corporation (MNC), some overseas subsidiaries of today's MNC have begun to take a more strategic role and participate in competence-creating research and development (R&D) activities that extend the profile of competencies of their MNC groups. In the large literature on subsidiary roles in the MNC, e.g. White and Poynter (1984), Bartlett and Ghoshal (1986), Cantwell and Mudambi (2005), a common inference has been an increase over time in the capacity of subsidiaries for knowledge sourcing both intra- and inter-organizationally. However, the implications for shifts in the global structure of knowledge development in MNCs still remain relatively unexplored, which motivates this paper.

The restructuring of MNCs, as knowledge creation has tended to become more geographically dispersed within the firm, requires a closer relationship between its intra- and inter-organizational networks. In this process, subsidiaries have come to play a critical role in knowledge generation (Birkinshaw, Hood, and Jonsson, 1998) sourcing knowledge from both their own internal MNC network, and from a local network of other organizations in which they need to be embedded to become locally creative (Andersson, Forsgren, and Holm, 2002). However, this process of business network formation simultaneously blurs the boundaries between firms, but erects new boundaries or divisions and creates new decentralized nodes of authority or influence within MNCs, given that subsidiaries or other sub-units independently initiate and participate in different networks, and that the headquarters of the firm is unlikely to be able to acquire or retain a full knowledge of these diverse networks as they develop.

Whereas transaction costs theory and evolutionary theory both stress the boundary between firms and external market in explaining the existence of firms, does the MNC break up given the blurred external boundary and newly emerged internal boundaries? In this study, we argued that instead of breaking up the MNC, the formation of open networks is bringing the transaction cost and the evolutionary accounts of the firm back closer together. On one hand, the open business networks may entail the management of potential conflicts of interest between parties emphasized by transaction cost approach; on the other, such networks can be viewed as co-evolving with the production (distribution) technology and capabilities of firms, which lies at the heart of the evolutionary or competence-based theory. Consequently, this paper aims to shed light on the linkages between intra-firm and inter-firm networks for knowledge development and exchange. Attention is paid to the changing nature of knowledge creation and exchange, especially the increasing complexity of knowledge creation.

Before discussing the role of complexity in subsidiary knowledge sourcing, we need to further clarify the term – knowledge sourcing – for the purposes of this paper. First of all, knowledge sourcing in this paper means the use of previous technological knowledge in the further development of that knowledge. The notion that technological innovation relies on the creation of tacit capability has been quite widely accepted. It is tacit because technological knowledge is embedded in the social culture, organizational structure, and routines of a firm. Although tacit capability cannot be measured directly, it has come to depend increasingly on a more and more extensive sophisticated underlying base of scientific and engineering knowledge. As such knowledge becomes more complex; it relies on a wider range of interdisciplinary foundations, drawn from a broader range of fields of expertise. To source technological knowledge for the purpose of further development firms draw on all their internal and external network linkages.

We used USPTO patent data from patents granted in 1975-1995 and found evidence that as technological complexity rises, firms tend to rely increasingly on inter-organizational networks to facilitate knowledge accumulation. Our findings are robust after controlling firm effects, industry effects, home country effects, time effects, geographical boundaries, host location effects, and even strategic considerations of firms. Therefore, this study contributes to a better understanding of both technological knowledge flows and strategic decisions of MNCs. This article is organized as follows: section 2 reviews the conceptual background of technological complexity and knowledge sourcing, and develops hypotheses; section 3 presents the empirical framework for this study; sections 4 and 5 discuss the results of our statistical analysis; while the final section provides some conclusions.

2. CONCEPTUAL BACKGROUND AND HYPOTHESES DEVELOPMENT

2.1 Conceptual Background

To explain the existence of the firm as a mode of economic organization and coordination (although not the heterogeneity of firms), transaction cost theorists have sometimes drawn a clear and sharp distinction between the apparently purely hierarchical coordination of economic activity within the firm, and the apparently purely nonhierarchical coordination of activity between firms or between firms and other actors, at arm's length through market relationships (by extension of the analysis of Coase, 1937). This approach is designed to establish whether a given set of exchange relationships is more efficiently conducted within firms in general, or instead in markets. In the simplest version of this story, there are clear and distinct boundaries between firms and markets (and hence between firms themselves, which are connected essentially just through markets), and no relevant boundaries or sub-divisions within firms.

In the Schumpeterian literature, attention shifted to the role of the firm as a continuous creator of knowledge through localized search efforts in and around production, which better explains firm heterogeneity (Nelson and Winter, 1982; Rosenberg, 1982; Nelson, 1991). However, such problem-solving efforts often call forth knowledge exchanges between firms, and between firms and non-firm actors. If the flows of knowledge between firms, and the extent to which firms draw upon external capabilities rises sufficiently, then the boundaries between firms may begin to become blurred. In large firms the evolutionary trajectories or paths of corporate technological learning also involve knowledge creation across various divisions or business units, and in multinational corporations (MNCs) they have increasingly involved knowledge creation both at home and in their foreign subsidiaries, and so knowledge often needs to flow within as well as between firms.

In this latter context, the barriers to knowledge exchange between different units of a large firm can become as much of an issue as the boundaries between firms, and in particular a tension may develop between the local inter-organizational networking relationships of an intra-firm unit, and its wider international networking relationships with other parts of its corporate group. Partly as a result of this line of research on international networks for knowledge creation or innovation (Hedlund, 1986; Cantwell, 1995), it has become apparent that such international business networks frequently need to be comprised and to connect both internal MNC networks (usually, across national borders) and various kinds of inter-firm networks (often arranged around a subsidiary within some local or regional geographical area).

The conventional analysis of governance structures in the coordination of economic activity might be represented by the dichotomy between markets and hierarchies (Williamson, 1975). This traditional approach entails a parent driven or headquarters-driven perception of the MNC. Subsidiaries were not thought to usually themselves the independent source of new creative initiatives within their corporate group. More recently, attention has been given to the possibilities of open networks that further blur the boundaries between firms. While open networks continuously open to extension to new partners and also open to selective withdrawals, a focal actor that is embedded in an open network may find that the network grows or contracts even without changes in that actor's own direct relationships. Moreover, so-called open innovation systems have even been held to be the major organizational form for the promotion of innovation by firms in the future (Chesbrough, 2003, 2006; Laursen and Salter, 2006). Under the open systems, the subsidiaries of MNCs are the organizations that mostly commonly connect the internal network relationship structure with the external network structures, just as parent companies are most commonly the intra-group entities that connect those relationships in conventional approach.

It is agreed that intra-MNC and inter-firm networks are complementary and interactive with one another. As external knowledge creation becomes more important, so the monitoring function of internal R&D becomes more significant. Inter-firm networks facilitate this monitoring function, if partners have complementary know-how, especially in they engage in cooperative learning activities. However, at least for large firms, cooperative research ventures that support innovation are generally a complement to, not a substitute for, in-house development. As a consequence, the firm's own problem solving and learning sets the agenda for what is usefully searched for when monitoring the external environment (Cantwell and Barrera, 1998).

However, given the blurring external boundary of firms, the implications of the emergence of more open systems for the internal organizational structures of firms has not much been explicitly addressed; for instance, given the blurring dichotomy between markets and hierarchies, does the MNC break up? This study sheds some light on this question by looking at the knowledge development and exchange of overseas subsidiaries of MNCs.

2.2 Hypotheses Development

There have clearly been various factors associated with the linkages between intra-firm and inter-firm networks for knowledge development and exchange. The increasing complexity of technology is one of the most obvious contributors. A large portion of patents in the 19th century were the outcome of individual inventors, e.g. Edison or Bell, but most current patents are invented by teams within and between firms, and in collaboration with other agencies. Moreover, the number of technologies required per product is increasing in many industries, as a result, for example, of the shift from mechanical to electro-mechanical to electronic systems in the automobile industry (Miller, 1994; Granstrand, Patel and Pavitt, 1997; Howells, James, and Malik, 2003). In the pharmaceutical industry the rise of biotechnology and ICT applications have been critical, as well as the role of optics and laser technologies for medical instruments. Therefore, companies increasingly have to deal with much more difficult and multidisciplinary technological problems. Another important factor influencing the complexity of today's technology is the blurring of the boundary between science and technology. A great many antecedents can be found in the history of science and technology, including the cases of pharmaceuticals, biotechnology, and the modern science of bacteriology. Yet with the limited resources and capability of a single company, and given the increasing costs of science-based research, as well as the persistence of the specific profile of specialization of firms due to the path dependent and tacit nature of technologies, such cross-boundary research issues encourage the seeking of outside support to overcome internal technical limitations. Consequently, we expect that:

Hypothesis 1: Ceteris Paribus, the more complex a piece of technological knowledge, the more likely it is sourced from inter-organizational sources rather than an intra-firm network.

Yet multinational subsidiaries have to balance between the pull towards integration and consistency within an MNC group network, both in technological and organizational terms, and the pull towards the technological strength and specialization of their host country environment (Phene and Almeida, 2003). Within the MNC network, multinational subsidiaries are able to draw upon the technology resources of their parent company and other overseas subsidiaries. The survey results of a group of MNCs in Greece indicated that the dominant technology source (65.6%) was ‘existing technology embodied in established products they produce’ inherited from the home location (Manolopoulos, Papanastassiou, and Pearce, 2005). Phene and Almeida (2003) found that subsidiaries serve as distributors of knowledge to other firms in the MNC, based on their study on MNC patents in the US semiconductor industry. Therefore, today, foreign subsidiaries not only serve the traditional function of adapting the parent’s technology to local market needs and providing technical support to local factories and customers, but have also become significant sources of technology development in their own right (Cantwell, 1995). To facilitate technology development, subsidiaries may go to suppliers, customers, universities and public institutions, and even competitors in local environment for knowledge sourcing, while local firms may possess advanced technological capability in some specialized areas that are not the forte of the MNC’s home country. Sometimes, such a knowledge searching may also extend beyond the boundary of the host country, with the assistance of modern communication technologies. Whereas some knowledge sourcing from distant locations may be unavoidable for subsidiaries with a reinforced product mandate role for regional or even world markets, for subsidiary capability development particularly in some specialized areas that are not the forte of the MNC parent company, it's the embeddedness within local business networks that matters the most. As a result, we hypothesize that:

Hypothesis 2: Ceteris Paribus, the local knowledge accumulation of a subsidiary is more likely to rely on inter-organizational sources rather than an intra-firm network, moderated by technological complexity.

Although MNCs have shown a greater internationalization of their R&D facilities recently, it depends upon the type of technological activity involved. The development of science-based fields of activity and an industry's core technologies appear to require a grater intensity of face-to-face interaction (Cantwell and Santangelo, 2000). Nonetheless, it may sometimes still be the case that science-based and firm- and industry-specific core technologies are dispersed internationally. The main factors driving the occasional geographical dispersion of the creation of these kinds of otherwise highly localized technologies are either locally embedded specialization which cannot be accessed elsewhere, or company-specific global strategies that utilize the development of an organizational complex international network for technological learning (Cantwell and Santangelo, 1999). For instance, Porter (1990) points to the emergence of geographically dispersed but specialized regions in various technologies and industries. An overseas subsidiary of a MNC in an innovative host country assumes some responsibilities for new knowledge searching; the location-specificity of the knowledge and practices absorbed by such subsidiaries, in turn, contributes to differentiation across subsidiaries within the MNC (Phene and Almeida, 2003).

The more typical pattern of international specialization in innovation activity within the MNC is for the development of technologies that are core to the firm's industry to be concentrated at home, while other fields of technological activity may be located abroad, and in this sense the internationalization of research tends to be complementary to the home base. Thus, when science-based technology creation is internationally dispersed it is more often attributable to foreign technology acquisition by the firms of 'other' industries. Evolutionary approaches (Nelson and Winter, 1982; Winter, 1987), as well as organizational learning theory (March and Simon, 1958), suggest that a firm, when seeking to innovate in terms of either technology or organization, will consider options in the neighborhood of its current activities to avoid attenuating its learning capability (Phene and Almeida, 2003). The 'absorptive capability' of Cohen and Levinthal (1990) implies a similar point regarding the search for new knowledge requiring a relevant established base on which to build. On the other side of the same coin, firms are also reluctant to take the risk of disclosing any of their core technologies (Granstrand, Patel and Pavitt, 1997). Consequently, we expect that:

Hypothesis 3: Ceteris Paribus, the closer a piece of technological knowledge to the expertise of parent MNC group, the less likely it is sourced from inter-organizational sources rather than an intra-firm network.

3. DATA AND METHODOLOGY

Due to the complexity of many current technologies, the pattern of knowledge accumulation may include a complicated cross-technology field, and/or cross-industry combination of knowledge sources, and sourcing activities may extend beyond the boundary of a firm or the boundary of the host country. Hence, in this study, we analyze patents granted to the largest firms in the pharmaceutical industry by the US Patent and Trademark Office (USPTO) for inventions attributable to inventors in their subsidiaries in Germany, to measure the complexity of their technological knowledge sourcing. The citation records of patents to earlier patents allow us to calculate various measures of knowledge accumulation that cuts across categories, such as when the technological classification of a cited patent differs from that of the citing patent, or is due to inventors located in other countries (not Germany), or is assigned to other organizations (not the same corporate group that is the assignee of the citing patent).

We use patents granted by the USPTO to the largest foreign-owned firms in the pharmaceutical industry that are due to their research facilities (inventors) located in the Germany between 1975 and 1995. With these citing patents as the reference category, we examine the pattern of the patents they cite (as an indicator of the technological knowledge sources on which they draw), in terms of a pairwise comparison of the technology fields of citing and cited patents. The 56 technological fields considered are derived from an appropriate combination of the classes and sub-classes of the US patent class system. In addition, a more aggregate level classification of a broad range of Chemical, Electrical, Mechanical and Transport technologies (CEMT) is constructed based on a further grouping of technology fields (Appendix A). Therefore, four categories of complexity are identified (in ascending order of the implied complexity of knowledge accumulation) in terms of the share of citations that are intra-technology field and intra-class, intra-technology field but inter-class, inter-technological field and intra-CEMT, and Inter-CEMT. The combination of these four categories allows us to study the extent of intra-class citation (the first category), intra-technology field citation (the first two combined), and intra-CEMT (the first three) knowledge sourcing. To capture subsidiary knowledge accumulation across organizational boundaries, we further constructed the category of intra-organizational knowledge sourcing, in which knowledge transfer occurs within or between the units of an MNC group; otherwise, knowledge transfer is inter-organizational. By the same token, we differentiated international knowledge sourcing from that which is local. International knowledge sourcing is from inventors in any location that is outside the host country. Thus, knowledge transfer from the US headquarters of an MNC to its German subsidiary is included in international knowledge sourcing.

We construct the dependent variable (INTERORG) as an indicator of whether a patent citation (a pairwise combination of citing and cited patents) is of an inter-organizational knowledge sourcing kind or not. In other words, INTERORG equals one if the citing patent cites a cited patent owned by another organization (i.e. other firms, universities, public institutes, government departments, and so forth); and zero, otherwise.

To measure technology complexity, we employ the technological field level 'technology relatedness index' from Cantwell and Noonan (2004), which is calculated as the joint occurrence for any given firm of a patenting presence in any pairwise combination of technological fields, for the world's largest firms in all industries for 1969-95, defining 'presence' in a field as a minimum of 5 patents granted in the period. The count of joint occurrences of 'presence' in technology fields i and j is used to construct a measure of relatedness of technology fields i and j. In this case, the 'technology relatedness index' (R index) has a maximum value of approximately 12, for technology fields for which i equals j (for intra-field sourcing), and so when two technology fields are highly related, the R index in this case approaches 12. The R index becomes negative for technology fields that are highly unrelated. For the purpose of current study, the R index is particularly useful in terms of measuring the complexity of knowledge sourcing between technological fields. By matching the technology fields of the citing patent and the cited patent, we can allocate a value of relatedness for each pair of patents according to their respective field classifications. But to measure technology complexity rather than technological proximity (R), we transform the R index into the 'Technology Distance Index' (D index) as follows:

$$Di = Max(R) - Ri \qquad (3)$$

where Di is the 'Technology Distance Index' for a pair of citing and cited patents i, and Ri is the R index for the combination of fields represented by pair i; Max(R) is the maximum value of R for any combination of fields (close to 12 in our case). After the transformation based on equation (3), for intra-technological field knowledge sourcing in which the citing patent and cited patent are in the same technological field, the D index equals zero, whereas the D index will rise to a very large positive value if the citation between the pair of patents is across technological fields that are highly unrelated. In other words, we set up a variable (D), which extends the simple inter-technological field measurements by allowing for the extent of relatedness between fields.

A dummy variable is used to measure the geographical dimension (INT) of the knowledge sourcing. INT equals one, when the knowledge sourcing is an international kind (outside the host country); zero otherwise.

We include two versions of variables to measure the distributions of the knowledge sourcing of firms: FMSHARE and FMRTA. For each assignee firm of citing patents, the FMSHARE is the firm's own share of total world patenting in a given field (not just by large firms), expressed as a percentage. The FMRTA employs a revealed technological advantage (RTA) index defined as follows:

$$RTA_{ij} = (P_{ij} / \sum_i P_{ij}) / (\sum_j P_{ij} / \sum_{ij} P_{ij}) \qquad (4)$$

where P_{ij} is the number of patents of firm i in field j. It is worth mentioning that the FMRTA in this study is calculated relative to all other large firms of any industry, and not just relative to firms within the same industry.

Finally, to capture the time effects, we divide the 21 years (Y) between 1975 and1995 into three periods, namely 1975-1981, 1982-1988, and 1989-1995, and include a variable measuring the three periods (P). We further control for an industry-specific effect (OUTPUT) by allowing for the industry of the firm to which citing patents are assigned. Since we use the patents of German subsidiaries of large foreign-owned pharmaceutical MNCs, the values of OUTPUT are limited to two industries – i.e. the chemical and the pharmaceutical industries. So another way of thinking of this distinction is between firms that are chemical generalists with some pharmaceutical activities, and those that are pharmaceutical specialists. In addition, we identified major regions in Germany and the home country of each subsidiary in this study to control for regional effects (RG) and home country effects (HM), respectively.

As INTERORG is a dichotomous variable that takes values of 1 and 0, we employ a logistic regression model. The model may be expressed formally as:

$$Y = f(X, C) \qquad (5)$$

where Y is the probability of knowledge being sourced inter-organizationally, viz. the probability of INTERORG equaling one; X is a vector of independent variables, and C is a vector of control variables.

4. RESULTS AND DISCUSSION

To briefly illustrate the pattern of knowledge accumulation over time, Table 1 provides a simplified demonstration by measuring technological complexity using inter- and intra-technology field knowledge sourcing. It shows that technology is increasingly complex over time.

It might be argued that greater complexity in knowledge sourcing (more inter-field diversity in patterns of knowledge accumulation) should be expected to be associated with a rise in inter-organizational sourcing. Just as more diverse fields of knowledge sourcing might require greater geographical diversity, so they might imply a need for greater inter-organizational transmissions (as in some explanations for increases in inter-firm alliances motivated by the needs of an exchange of complementary technological knowledge). However, at least in the aggregate there has been on average an opposite shift, from inter-organizational towards greater intra-firm sourcing (see the last column in Table 1). This concurs with the findings of Jaffe and Trajtenberg (1999) - who show, in their by now familiar alternative terminology, a rise in the share of 'self-cites' since the 1960s or 1970s. However, the explanation for this latter trend that we find here is very interesting. It turns out the rise in the share of intra-firm citation is entirely attributable to international flows (at least in the German pharmaceutical industry case). But a reverse trend is observed for inter-organizational knowledge accumulation. That is, in local sourcing there is a shift from intra-firm accumulation (discrete knowledge building within a subsidiary) towards inter-organizational flows (a wider variety of sources from the subsidiary's environment). In contrast, in international sourcing we find the effect that dominates in the total picture, namely a shift towards intra-firm knowledge building, through an increase in intra-MNC cross-border flows.

Elsewhere it has been argued (Cantwell and Janne, 1999; Cantwell and Piscitello, 2000) that the increases in technological specialization that have been observed at a subsidiary level are indicative of a restructuring of MNC international networks, and a greater reliance upon those networks for (geographically dispersed) knowledge creation in MNCs. The reply of those more skeptical of the evolution of such internationally heterarchical intra-MNC network formations, such as Solvell and Zander (1998), or Yamin and Forsgren (2006) has been to point out that increasing affiliate specialization yielded no direct evidence of the necessary corollary for internal MNC knowledge flows of the proposition that the rise in subsidiary specialization was to be explained by cross-border MNC restructuring – as opposed to the alternative supposition of subsidiaries just going their own way. Namely, the necessary corollary is that there should be greater knowledge flows (a greater intensity of technological knowledge exchange) within the MNC across national boundaries. Now we have here some evidence for just this pattern in the restructuring of MNC knowledge flows. The shift towards international knowledge sourcing is largely an intra-firm shift.

So we have a restructuring of knowledge networks precisely along the lines hypothesized in the literature on the reorganization of the MNC to facilitate a dispersion of knowledge creating activities (such as Hedlund, 1986) - that is, more intra-MNC sourcing internationally, but more inter-organizational sourcing at the level of the local subsidiary network. However, returning to the central argument about the implications of greater complexity in knowledge sourcing, there has been a shift towards inter-field citation in both intra-MNC and inter-organizational sourcing. That is, both the intra-firm (international) and the inter-organizational (local) networks have been restructured to deal with the greater complexity of knowledge accumulation, and the need for both networks to support the required degree of knowledge diversification (as again has been argued for some time in the literature that relates the recent internationalization of corporate research facilities to technological diversification).

Moreover, we find indeed that the shift in local sourcing from the intra-subsidiary to the inter-organizational is due mainly to a decline in discrete or autonomous intra-field knowledge accumulation within subsidiaries (and a growing reliance on the parent company for intra-field sources), viz. the intra-firm and intra-tech local knowledge sourcing decreased by 3.79%, from 7.90% to 4.11% (and the Intra-Firm and Intra-Tech knowledge sourcing from international resources increased by 2.89%, from 4.40% to 7.29%). Likewise, the shift in international sourcing, in the opposite direction from the inter-organizational to the intra-MNC, is attributable primarily to a shift in the organizational composition of intra-field sourcing across borders, in favour of a greater reliance on one's own MNC group network rather than upon other organizations in the rest of the world. Table 1 shows that for international knowledge accumulation, intra-firm knowledge sourcing increased for both intra-tech and inter-tech categories by 2.89%, and 3.43%, respectively. But another way of looking at this, which takes us beyond the simple network restructuring story just referred to, is technological complexity; viz. most striking shift shown in Table 1 can be found within international inter-organizational flows, away from intra-field and towards inter-field citation. In this domain intra-field citation fell by over 12% of total citations, while inter-field citation rose by over 8%.

So this brings us back to the reasoning associated with our initial supposition that increased knowledge complexity might be expected to mean more inter-organizational sourcing. While in the aggregate this is false (‘self-cites’ rise), where the logic does apply strongly is with respect to what firms take from others (inter-organizational flows) located elsewhere in the world. Foreign-owned subsidiaries in the German pharmaceutical industry have come to rely on other organizations across the world far more for diverse knowledge sourcing, and so in this sphere greater knowledge complexity has been accompanied by both geographical and organizational distance.

Table 2 shows the two-tailed Pearson correlation matrix of variables. No problematic correlation is observed. Table 3 reports the logistic regression coefficients for variables predicting inter-/intra-organizational knowledge sourcing using all the observations in our dataset (i.e. a total of 13,732 pairs of patents). All the models in Table 3 are statistically significant. The positive and highly significant coefficients on variable D in Table 3 are consistent with our proposition that a firm is more likely to source knowledge outside the firm's own internal network when technology complexity is greater. This provides very strong support for our Hypotheses 1 that as technology complexity rises, so will inter-organizational sourcing. Variable P and its interaction with D confirm the results obtained in Table 1, viz. inter-organizational knowledge sourcing decreases over the three periods. This is consistent with our findings above that at least in the aggregate there has been the shift from inter-organizational towards greater intra-firm sourcing over time.

Variable INT is positively significant. It means that the probability of international inter-organizational knowledge sourcing is on average significantly higher than that of the local inter-organizational knowledge sourcing. In other words, locally a higher proportion of knowledge accumulation is still due to a cumulative intra-subsidiary process, which seems to be contradictory to our findings in Table 1, namely that the shift towards international knowledge sourcing is largely an intra-firm shift. However, the interaction of INT and D sheds some light on this puzzle. The coefficient of the interaction is negatively significant across all the models, which means that subsidiaries are more likely to source complex technological knowledge from local inter-organizational knowledge sources and to source less complex technological knowledge through cross-border intra-firm network. Therefore, our Hypothesis 2 is confirmed. Table 4 further investigates this below.

FMSHARE is used in Models 6 and 7 to measure firm specific effects, whereas Models 8 and 9 use FMRTA. Basically, the results for these two versions of measurement for the firm's own distribution of activity are consistent, i.e. firms that have a large share of activities in a certain field (FMSHARE), or that are highly specialized in a certain field (RTA), tend to have less inter-organizational knowledge sourcing in that field, and vice versa. In other words, Hypothesis 3 is confirmed. Put another way, the more remote a piece of technology is from a firm's existing knowledge, the more difficult it is for the firm to understand if it has limited experience in the relevant set of technological fields; therefore it becomes more likely the firm will source outside its own internal network, even if that entails some international tie-up.

The control for industry - OUTPUT – is positive and reaches significance when we use the FMRTA as the control for firm effects in Models 8 and 9. As the reference group for OUTPUT is the chemical industry, this result means that pharmaceutical specialists are more likely to have inter-organizational knowledge sourcing than those in chemical industry, controlling for other variables in the models. This may reflect their narrower scope. Finally, the effects of control variables RG and HM are basically consistent across Model 6 to Model 9. The results show that the US-owned firms rely more on knowledge sourcing from within their own internal networks than do MNCs of *any* other nationality of origin. This may be partly explained by the strength of the US in the bio-pharmaceutical industry.

To further clarify the above results, we divided the data into two subsets: those observations that depict international knowledge sourcing (observations with INT=1), and the local knowledge sourcing observations (observations with INT=0). The Logistic regression results are reported in Tables 4(a) and 4(b), respectively.

The coefficients of D in Tables 4(a) show that technological complexity leads to inter-organizational knowledge sourcing only to a lesser extent internationally (i.e. the internal MNC network is critical for this purpose), whereas those in Table 4(b) show that locally inter-organizational networks are crucial for complex technological knowledge sourcing. In the former case, the restructuring of intra-firm across border network has included a significant intra-field component (also see Table 1). Due to the local nature of technological search (Atkinson and Stiglitz, 1969; Antonelli, 1995, 2005) firms tend to explore in the neighborhood of their current corporate knowledge when they look for new combinations connected with their core capabilities, in order to incorporate greater technological complexity. Thus, firms acquiring knowledge in distant technological fields are most interested in exploring combinations between these as yet unrelated technological fields and their established core, through a process of experimentation. For a subsidiary, the core established knowledge base of the firm is typically derived from its intra-firm MNC group network (and in particular, from its parent company). Thus, as a subsidiary moves into new areas of technological experimentation, it attempts to combine these with the full (intra-field) knowledge base of the corporate group. So international knowledge flows within a more integrated MNC group are often still intra-field. The latter phenomenon is consistent with the argument that in this case foreign-owned subsidiaries are attracted to undertake research locally by the presence of other innovative resources in a specialized center of excellence. Germany is a center of excellence for the pharmaceutical and chemical industries. To a large extent, foreign-owned MNCs invest in Germany to tap into the expertise in pharmaceutical and chemical fields associated with the location and indigenous firms. To be able to take advantage of location resource availabilities, foreign-owned subsidiaries need to establish extensive external network linkages with local players (firms, universities, public institutes, and so forth), i.e. the need to become local embedded. However, as we have discussed above, a greater technological complexity of knowledge accumulation occurs mainly through knowledge combinations across technology fields. According to Nightingale (2000), the most advanced research areas in pharmaceuticals rely increasingly on information and communication technology (ICT). Therefore, subsidiaries might also need to source knowledge internationally from other centers of excellence, such as from the US for ICT applications in pharmaceutical technologies. Consequently, technological complexity leads to a greater reliance on inter-firm local networks, but both intra-MNC and inter-organizational relationships across borders.

For variables FMSHARE and FMRTA, Tables 4a) and 4b) show findings that are quite consistent with those of Table 3. However, the coefficients on OUTPUT in Table 4a) show that firms in the pharmaceutical industry (OUPUT=1) are more likely to engage in international inter-organizational knowledge accumulation, while those in Table 4b) show that the inter-organizational knowledge accumulation of firms in chemical industry (OUTPUT=0) are more likely to be localized. This finding is consistent with that of Gittelman and Kogut (2003) on biotech firms. While pharmaceutical firms are much closer to biotech firms, in that they both heavily rely on scientific knowledge, pharmaceutical specialists are more internationally oriented like biotech firms in their involvement in knowledge networks, but chemical generalists tend to be more locally oriented, in terms of their inter-organizational network linkages.

We further tested the robustness of our models by including Granstrand, Patel and Pavitt's (1997) technological categories, namely core, niche, background and marginal technologies, to control for strategic consideration of firms; also some different measures of regional effects and home country effects are employed. The main results we found above are consistently hold (details available from the authors on request).

5. CONCLUSIONS

By focusing on knowledge sourcing within internal MNC networks, as well as inter-firm knowledge spillovers, this study contributes to our understanding of how the complexity of technology has affected the relationship between internal and external networks, the strategic choice of firms, and organizational restructuring. First of all, as technological complexity rises, firms tend to increasingly rely on both international and local inter-organizational networks to facilitate knowledge accumulation. Our findings are robust in models with various control variables and in robustness tests. However, we found that the influence of technological complexity on local inter-organizational knowledge accumulation is much stronger than that on international inter-organizational knowledge sourcing. This might be due to firms choosing to go to Germany for pharmaceutical expertise, given the fact that Germany is a specialized center of excellence of pharmaceutical related technologies. Hence, this study may also shed light on the nature of knowledge accumulation in an all-round center of excellence. As argued in regional innovation system literatures, while specialized centers of excellence entail intra-industry inter-firm knowledge spillovers, all-round centers incorporate the scope for wider inter-industry knowledge spillovers around certain GPTs. In other words, subsidiaries in a specialized center are more likely to source knowledge locally, since the knowledge generated and sourced in such center is largely industry-specific. While GPTs can be applied in most industries, subsidiaries located in all-round centers are concerned to develop niche applications of GPTs especially relevant to their own industry, so they need to combine local GPT knowledge with industry-specific knowledge that is more likely to be drawn upon elsewhere, e.g. peer subsidiaries in specialized centers or from their parent company (Cantwell and Iammarino, 2000; Cantwell and Piscitello, 2002). While niche technologies developed in all-round centers are transferred, the knowledge flows are largely limited within MNC's own internal network.

Secondly, contrary to the argument of Solvell and Zander (1998) or Yamin and Forsgren (2006), we have found that the restructuring and intensification of knowledge exchange mechanism in MNCs are essential for subsidiaries to play a more creative role in knowledge generation. It has been argued that both the local embeddedness and the capabilities of a subsidiary determine its knowledge sourcing pattern, viz. a subsidiary's ability to gain access to local knowledge sources is likely to be dependent upon its embeddedness in the host country (Cantwell and Mudambi, 2003; Frost, 2001), and the characteristics of a local subsidiary also represent its capability in absorbing knowledge (Cohen and Levinthal, 1990; Cantwell, 1989; and Singh, 2007); for example, whether a subsidiary can generate positive spillovers through its own R&D activities or through knowledge flows within its group may influence local perceptions of its worthiness and credibility as an exchange partner within local knowledge-sharing networks (Cantwell and Barrera, 1998; and Frost, 2001). While local external embeddedness might helps a subsidiary to acquire the competence-creating mandate (Cantwell and Mudambi, 2001 and 2003), to maintain such a role, interdependency between the subsidiary and other units in the MNC is essential; otherwise the subsidiary may end up as an isolated entity and finally lose its interests in the MNC group (Birkinshaw and Hood, 1998). In other words, when sourcing knowledge from both their own internal MNC network, and from a local network of other organizations, subsidiaries need to be increasingly embedded in knowledge flows in both these networks in order to become locally creative (Andersson, Forsgren, and Holm, 2002). Our study supports this outlook by showing that local inter-organizational knowledge accumulation has steadily increased over a 21-year period, and meanwhile intra-subsidiary accumulated knowledge has been transferred more intensively among the internal units of an MNC over the same period.

Our findings further contribute to the literature of open innovation systems. The MNC can now be perceived as being embedded in a series of internal and external business networks (Frosgren, Holm and Johanson, 2005). This process blurs the boundaries between firms, but erects new boundaries or divisions and creates new decentralized nodes of authority or influence within MNCs. The purposeful knowledge sourcing of subsidiaries from both intra- and inter-firm sources showed in this study provide empirical evidence of the shifting of internal organizational structure due to the emergence of more open innovation systems. Increasingly, the subsidiaries of MNCs, instead of parent companies, become the intra-group organizations that most commonly connect the internal network relationship structure with the external network structure.

Finally, while US-owned firms are generally more likely to engage in intra-organizational knowledge accumulation than firms from other nationalities of origin, we have found that some firms might employ particular knowledge management strategies for knowledge sourcing, which are a combination of strategic acquisition and technological specialization. Besides the forces of technological complexity, a firm may consciously make strategic choices to become increasingly complementarily specialized in their in-house technological profile, instead of diversified. This might also suggest that firms can take active and deliberate decisions to influence their knowledge accumulation trajectory, rather than to merely passively follow a given course.

Our findings are based on foreign-owned subsidiaries in Germany and are limited to the pharmaceutical industry; therefore, extending this to other countries or other industries can be explored in the future. Moreover, future studies on combining knowledge sourcing strategies and other strategies would be fruitful and greatly contribute to both the international business and corporate strategy literatures.

Reference

Andersson, U, Forsgren, M., Holm, U. 2002. The strategic impact of external networks: subsidiary performance and competence development in the multinational corporation. *Strategic Management Journal,* 23(11): 979-996.

Antonelli, C. 1995. *The Economics of Localised Technological Change and Industrial Dynamics*. Kluwer Academic Press, Dordrecht.

Antonelli, C. 2005. The Economics of Localized Technological Change: The Role of Creative Adoption. In Santangelo G. D. (Ed.) *Technological Change And Economic Catch-up The Role Of Science And Multinationals*. Cheltenham: Edward Elgar.

Atkinson, A. B., Stiglitz, J. E. 1969. A new view of technological change. *The Economic Journal*, 69: 573-578.

Bartlett, C. A., Ghoshal, S. 1986. Tap your subsidiaries for global reach. *Harvard Business Review*, 87–94.

Birkinshaw, J., Hood, N. 1998. Multinational subsidiary development: capability evolution and charter change in foreign-owned subsidiary companies. *Academy of Management Review*, 23(4): 773-795.

Birkinshaw, J., Hood, N., Jonsson, S. 1998. Building firm specific advantages in multinational corporations: The role of subsidiary initiative. *Strategic Management Journal*, 19(3): 221-241.

Cantwell, J.A. 1989. A dynamic model of the post-war growth of international economic activity in Europe and the USA. In *Technological Innovation and Multinational Corporations,* Oxford: Basil Blackwell.

Cantwell, J. 1995. The globalization of technology: What remains of the product cycle. *Cambridge Journal of Economics*, 19: 155–174.

Cantwell, J. 2004. An historical change in the nature of corporate technological diversification. In Cantwell, J., Gambardella, A., and Granstrand, O. (Ed.), *The Economics and Management of Technological Diversification*. Routledge: London.

Cantwell, J.A., Barrera, M.P. 1998. The localisation of corporate technological trajectories in the interwar cartels: cooperative learning versus an exchange of knowledge. *Economics of Innovation and New Technology*, 6(2-3): 257-290.

Cantwell, J. A., Colombo, M. G. 2000. Technological and Output Complementarities: Inter-Firm Cooperation in Information Technology Ventures. *Journal of Management and Governance*, 4: 117-147.

Cantwell, J.A., Iammarino, S. 2000. Multinational corporations and the location of technological innovation in the UK regions. *Regional Studies*, 34(4): 317-332.

Cantwell, J., Janne, O. 1999. Technological globalisation and innovative centres: the role of corporate technological leadership and locational hierarchy. *Research Policy*, 28(2/3): 119-144.

Cantwell, J.A., Mudambi, R. 2001. MNE competence-creating subsidiary mandates: an empirical investigation. *University of Reading Discussion Papers in International Investment and Management*, 285: July.

Cantwell, J.A., Mudambi, R. 2003. On the nature of knowledge creation in MNE subsidiaries: an empirical analysis using patent data. Paper presented at the *DRUID Summer Conference*, Copenhagen.

Cantwell, J., Mudambi, R. 2005. MNE competence-creating subsidiary mandates. *Strategic Management Journal*, 26: 1109-1128.

Cantwell, J., Noonan, C. 2004. Technology Relatedness: 1890 – 1995. *Academy of Management Conference*, New Orleans, August 6-11.

Cantwell, J., Piscitello, L. 2000. Accumulating technological competence: its changing impact on corporate diversification and internationalization. *Industrial & Corporate Change*, 9(1): 21-50.

Cantwell, J.A., Piscitello, L. 2002. The location of technological activities of MNCs in European regions: the role of spillovers and local competencies. *Journal of International Management*, 8(1): 69-96.

Cantwell, J.A. and Santangelo, G.D. 1999. The Frontier of International Technology Networks: Sourcing Abroad the Most Highly Tacit Capabilities. *Information Economics and Policy*, 11(1): 101-23.

Cantwell, J.A. and Santangelo, G.D. 2000. Capitalism, Innovation and Profits in the New Techno-Economic Paradigm. *Journal of Evolutionary Economics*, 10(1-2): 131-57.

Chesbrough, H. 2003. *Open Innovation: The New Imperative for Creating and Profiting From Technology*. Boston, Mass.: Harvard Business School Press.

Chesbrough, H. 2006. *Open Business Models: How to Thrive in the New Innovation Landscape*. Boston, Mass.: Harvard Business School Press.

Coase, R. H. 1937. The Nature of the Firm. *Economica*, 4(4): 386-405.

Cohen, W., Levinthal, D. 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35: 128–152.

Frost, T.S. 2001. The geographic sources of foreign subsidiaries' innovations. *Strategic Management Journal*, 22(2): 101-123.

Gittelman, M., B. Kogut 2003. Does Good Science Lead to Valuable Knowledge? Biotechnology Firms and the Evolutionary Logic of Citation Patterns. *Management Science*, 49(4): 366-382. Special Issue: "Managing Knowledge in Organizations".

Granstrand, O., Patel, P., Pavitt, K. 1997. Multitechnology corporations: Why they have distributed rather than distinctive core competencies. *California Management Review*, 39(4): 8–25.

Hedlund, G. 1986. The Hypermodern MNC—A Heterarchy? *Human Resource Management*, 25(1): 9-35.

Howells, J., James, A., Malik, K. 2003. The sourcing of technological knowledge: distributed innovation processes and dynamic change. *R&D Management*, 33(4): 395-409.

Jaffe, A. B., Trajtenberg, M. 1999. International Knowledge Flows: Evidence From Patent Citations. *Economics of Innovation & New Technology*, 8(1/2): 105-136.

Laursen, K. and Salter, A. 2006. Open for Innovation: The Role of Openness in Explaining Innovation Performance Among U.K. Manufacturing Firms. *Strategic Management Journal*, 27(2): 131–50.

Manolopoulos, D., Papanastassiou, M., Pearce, R. 2005. Technology sourcing in multinational enterprises and the roles of subsidiaries: An empirical investigation. *International Business Review*, 14: 249-267.

March, J., Simon, H. 1958. *Organizations*. New York: Wiley.

Miller, R. 1994. Global R&D networks and large-scale innovations: the case of the automobile industry. *Research Policy*, 23: 27-46.

Nelson, R.R. 1991. Why Do Firms Differ, and How Does it Matter? *Strategic Management Journal*, 12(1): 61–74.

Nelson, R., Winter, S. 1982. *The evolutionary theory of the firm*. Cambridge: Harvard University Press.

Nightingale, P. 2000. Economies of scale in experimentation: knowledge and technology in pharmaceutical R&D. *Industrial and Corporate Change*, 9: 315-359.

Phene, A., Almeida, P. 2003. How do firms evolve? The patterns of technological evolution of semiconductor subsidiaries. *International Business Review*, 12: 349-367.

Porter, M. 1990. *The Competitive Advantage of Nations*. New York: Free Press.

Rosenberg, N. 1982. *Inside the Black Box: Technology and Economics*. Cambridge and New York: Cambridge University Press.

Singh, J. 2007. Asymmetry of knowledge spillovers between MNCs and host country firms. *Journal of International Business Studies*, 38: 764-786.

Solvell, O., Zander, I. 1998. International diffusion of knowledge: isolating mechanisms and the role of the MNE. In Chandler, A., Hagstrom, P., and Solvell, O. (Ed.), *The Dynamic Firm: The Role of Technology, Strategy, Organization, and Regions.* Oxford University Press.

White, R., Poynter, T. 1984. Strategies for foreign owned subsidiaries in Canada. *Business Quarterly,* 48(4): 59–69.

Williamson, O.E. 1975. *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: Free Press.

Winter, S. 1987. Knowledge and competence as strategic assets. In D. Teece (Ed.), *Competitive challenge*. Cambridge: Ballinger.

Yamin, M., Forsgren, M. 2006. Hymer's Analysis Of The Multinational Organization: Power Retention And The Demise Of The Federative MNE. *International Business Review*, 15(2): 166-179.

Zander, I., Sölvell, Ö. 2002. The phantom multinational. In Havila, V., Forsgren, M. and Håkanson, H. (Ed.), *Critical Perspectives on Internationalisation*. New York: Pergamon

Table 1. The Pattern of Knowledge Accumulation Over Time

Geographical Boundary	Organizational Boundary	Tech-Complexity	1975-1981	1982-1988	1989-1995	CHANGE
International	Inter-Org	Inter-Tech	23.06	31.08	31.30	8.24
		Intra-Tech	51.50	44.04	38.97	-12.53
	Intra-Firm	Inter-Tech	1.80	2.76	5.23	3.43
		Intra-Tech	4.40	3.96	7.29	2.89
Local	Inter-Org	Inter-Tech	2.65	3.09	3.70	1.05
		Intra-Tech	6.15	6.63	6.81	0.66
	Intra-Firm	Inter-Tech	2.54	2.15	2.60	0.06
		Intra-Tech	7.90	6.29	4.11	-3.79

Table 2. Pearson Correlation Matrix (Two-Tailed)

	Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
1	**Intra-/Inter-Org**	0.8276	0.3777	1.0000									
2	**Tech Distance (D)**	0.3823	0.4860	0.0660 (<.0001)	1.0000								
3	**Periods (P)**	2.1483	0.8121	-0.0320 (0.0002)	0.1141 (<.0001)	1.0000							
4	**Years (Y)**	12.0746	6.0293	-0.0499 (<.0001)	0.1189 (<.0001)	0.9433 (<.0001)	1.0000						
5	**International (INT)**	0.8195	0.3846	0.3538 (<.0001)	0.0854 (<.0001)	0.0212 (0.0132)	0.0198 (0.0205)	1.0000					
6	**Industry (OUTPUT)**	4.1955	0.3966	-0.0435 (<.0001)	-0.0917 (<.0001)	-0.0805 (<.0001)	-0.0928 (<.0001)	-0.0633 (<.0001)	1.0000				
7	**Region (RG)**	10206	4.1110	0.0631 (<.0001)	-0.0010 (<.0001)	-0.0752 (<.0001)	-0.0739 (<.0001)	0.0363 (<.0001)	-0.1348 (<.0001)	1.0000			
8	**Home Country (HM)**	5.7604	3.6965	0.0446 (<.0001)	0.0286 (<.0001)	-0.0276 (0.0012)	-0.0345 (<.0001)	-0.0106 (0.2165)	-0.3783 (<.0001)	-0.0934 (<.0001)	1.0000		
9	**Share of Activities (FMSHARE)**	1.2320	1.6756	-0.1902 <.0001	-0.1384 <.0001	0.1237 <.0001	0.1290 <.0001	-0.0341 <.0001	-0.1499 <.0001	-0.2549 <.0001	0.1585 <.0001	1.0000	
10	**Firm RTA (FMRTA)**	3.7138	3.6447	-0.0931 <.0001	-0.2113 <.0001	-0.0898 <.0001	-0.1147 <.0001	-0.0968 <.0001	0.2014 <.0001	-0.0095 0.2683	0.0122 0.1523	0.3706 <.0001	1.0000

Table 3. Logistic Regression Coefficients for Variables Predicting Inter-/Intra-Organizational Knowledge Sourcing (All Observations by Periods)

	Models	1	2	3	4	5	6	7	8	9
	Constant	1.4480***	1.7260***	1.6223***	0.3568***	0.3234***	0.1934	0.1900	-0.1569	-0.1817
1	**Tech Distance (D)**	**0.0502*** **	**0.0535*** **	**0.1119*** **	**0.0897*** **	**0.1078*** **	**0.0689*** **	**0.0692*** **	**0.0689*** **	**0.0803*** **
2	**Periods (1-3) (P)**		**-0.1317*** **	**-0.0840** **	**-0.1212*** **	**-0.1232*** **	-0.0450	-0.0457	**-0.0654* **	**-0.0632* **
	1 * 2			**-0.0249*** **	**-0.0229** **	**-0.0220** **	-0.0134	-0.0131	-0.0108	-0.0117
3	**Geo Boundary (INT)**				**1.9097*** **	**1.9687*** **	**2.0516*** **	**2.0505*** **	**2.0175*** **	**2.0193*** **
	1 * 3					**-0.0286* **	**-0.0333** **	**-0.0329** **	**-0.0304* **	**-0.0314** **
4	**Patenting Share (FMSHARE)**						**-0.2582*** **	**-0.2554*** **		
	1 * 4							-0.0011		
5	**Firm's RTA (FMRTA)**								**-0.0564*** **	**-0.0517*** **
	1*5									-0.0029
6	**Industry (OUTPUT)**						-0.0238	-0.0230	**0.4589*** **	**0.4575*** **
7	**Bayern**						**-0.1779** **	**-0.1764** **	-0.114	-0.1153
	Berlin						**1.1643* **	**1.1644* **	**1.3706** **	**1.3669** **
	Brandenburg						12.9295	12.9241	13.3737	13.3977
	Bremen						13.2829	13.285	13.1858	13.1933
	Hamburg						0.1277	0.1296	0.3737	0.3762
	Hessen						-0.00172	-0.00184	0.0287	0.0322
	Niedersachsen						-0.0855	-0.0858	-0.0726	-0.077
	Nordrhein-Westfalen						**-0.1744** **	**-0.1734** **	0.00957	0.0044
	Rheinland-Pfalz						**0.6119*** **	**0.6116*** **	**0.7321*** **	**0.7317*** **
	Saarland						-0.0971	-0.0994	0.3157	0.2980
	Sachsen						-0.522	-0.5208	-0.5429	-0.5405
	Sachsen-Anhalt						-0.4802	-0.4778	-0.2853	-0.2933
	Schleswig-Holstein						0.2879	0.2900	**0.5123** **	**0.5173** **
	Thuringen						-0.3311	-0.3309	-0.0716	-0.0874
8	**UK**						**1.2116*** **	**1.2134*** **	**1.5335*** **	**1.5342*** **
	Italy						12.8085	12.8087	13.1472	13.1493
	France						**2.7092*** **	**2.7097*** **	**3.0560*** **	**3.0508*** **
	Japan						**1.5714** **	**1.5689** **	**1.9717*** **	**1.9647*** **
	Netherlands						**0.7502*** **	**0.7510*** **	**1.1939*** **	**1.1932*** **
	Belgium						**0.5178*** **	**0.5199*** **	**0.9984*** **	**0.9989*** **
	Switzerland						**0.4769*** **	**0.4772*** **	**0.2674*** **	**0.2690*** **
	Sweden						1.0294	1.0340	1.1934	1.2093
	Denmark						12.3733	12.3758	12.7808	12.7773
	Psuedo R2	0.0076	0.0102	0.0112	0.1700	0.1704	0.2335	0.2335	0.2157	0.2159
	Degree of Freedom	1	2	3	4	5	30	31	30	31
	Model chi-square (13732 obs)	62.5199***	84.3618***	92.8063***	1480.8922***	1484.4924***	2077.2727***	2077.3713***	1907.3983***	1909.436***

Notes:1. * p < 0.10; ** p < 0.05; *** p < 0.001.

2. Predicting the probability of Inter-Organizational knowledge sourcing

3. Reference group for 'Geo Boundary' is 'Local'; Reference group for 'Indsutry' is 'industry = 4' - the Chemical industry; Reference group for 'Region' is 'Region = Baden-Wurttemberg'; Reference group for 'Home Country' is 'Home Country = USA'

Table 4 a). Logistic Regression Coefficients for Variables Predicting Inter-/Intra-Organizational Knowledge Sourcing ('International' by Periods)

	Models	1	2	3	4	5	6	7
	Constant	2.0327***	3.0221***	3.0414***	2.5556***	2.5884***	2.3003***	2.3021***
1	**Tech Distance (D)**	**0.0232*****	**0.0331*****	0.0239	-0.0461	**-0.0524***	-0.0375	-0.0382
2	**Periods (1-3) (P)**		**-0.4486*****	**-0.4569*****	**-0.2868*****	**-0.2853*****	**-0.3107*****	**-0.3108*****
	1 * 2			0.0038	**0.0200***	0.0186	**0.0200***	**0.0200***
3	**Patenting Share (FMSHARE)**				**-0.2806*****	**-0.2960*****		
	1 * 3					0.0058		
4	**Firm's RTA (FMRTA)**						**-0.1032*****	**-0.1035*****
	1*4							0.0002
5	**Industry (OUTPUT)**				**0.1796***	**0.1724***	**0.8522*****	**0.8526*****
6	**Bayern**				-0.0171	-0.0257	0.0206	0.0206
	Berlin				**1.9420***	**1.9448***	**2.1197****	**2.1203****
	Brandenburg				14.6084	14.6424	15.1169	15.1156
	Bremen				14.1189	14.0924	13.7057	13.7041
	Hamburg				0.3077	0.2993	**0.4897***	**0.4895***
	Hessen				**0.2115****	**0.2123****	**0.2032****	**0.2031****
	Niedersachsen				**1.3440*****	**1.3570*****	**1.1984*****	**1.1988*****
	Nordrhein-Westfalen				-0.0771	-0.0769	0.1282	0.1287
	Rheinland-Pfalz				0.3273	0.3274	**0.4713****	**0.4709****
	Saarland				14.3658	14.3652	14.7566	14.758
	Sachsen				0.5112	0.5017	0.3695	0.3691
	Sachsen-Anhalt				12.4635	12.4458	12.6266	12.6251
	Schleswig-Holstein				0.3099	0.3021	**0.4379***	**0.4374***
	Thuringen				-0.8351	-0.8242	-0.5011	-0.4994
7	**UK**				**0.7134*****	**0.7035****	**1.0027*****	**1.0023*****
	Italy				14.4018	14.3993	14.7467	14.7456
	France				14.397	14.4000	14.7326	14.7332
	Japan				**1.8013***	**1.8339***	**2.2028****	**2.2038****
	Netherlands				**2.1145*****	**2.1108*****	**2.6803*****	**2.6803*****
	Belgium				**4.2766*****	**4.2663*****	**4.8259*****	**4.8263*****
	Switzerland				**0.3254*****	**0.3240*****	0.1202	0.1200
	Sweden				0.5512	0.5265	0.325	0.3235
	Denmark				13.8438	13.8300	14.1925	14.193
	Psuedo R2	0.0015	0.0248	0.0248	0.2048	0.2051	0.1856	0.1856
	Degree of Freedom	1	2	3	28	29	28	29
	Model chi-square (11253 obs)	8.1863**	139.9858***	140.0929***	1213.7834***	1215.8244***	1094.3716***	1094.3781***

Notes: 1. * p < 0.10; ** p < 0.05; *** p < 0.001.

2. Predicting the probability of Inter-Organizational knowledge sourcing

3. Reference group for 'Indsutry' is 'industry = 4' - the Chemical industry; Reference group for 'Region' is 'Region = Baden-Wurttemberg'; Reference group for 'Home Country' is 'Home Country = USA'

Table 4b). Logistic Regression Coefficients for Variables Predicting Inter-/Intra-Organizational Knowledge Sourcing ('Local' by Periods)

	Models	1	2	3	4	5	6	7
	Constant	0.0729	-0.5226***	-0.7401***	0.5433**	0.5361**	0.1099	0.0648
1	**Tech Distance (D)**	**0.0518*** **	**0.0435*** **	**0.1723*** **	**0.1643*** **	**0.1647*** **	**0.1740*** **	**0.1974*** **
2	**Periods (1-3) (P)**		**0.2906*** **	**0.3942*** **	**0.1979*** **	**0.1967*** **	**0.2172*** **	**0.2220*** **
	1 * 2			**-0.0569*** **	**-0.0534*** **	**-0.0525*** **	**-0.0536*** **	**-0.0558*** **
3	**Patenting Share (FMSHARE)**				**-0.1390*** **	**-0.1346*** **		
	1 * 3					-0.0022		
4	**Firm's RTA (FMRTA)**						**0.0068*** **	0.0152
	1*4							-0.0058
5	**Industry (OUTPUT)**				**-0.8518*** **	**-0.8507*** **	**-0.6620*** **	**-0.6610*** **
6	**Bayern**				**-0.4543*** **	**-0.4499*** **	**-0.3741*** **	**-0.3768*** **
	Berlin				0.2961	0.2996	0.4448	0.4715
	Bremen				13.5541	13.5553	13.7083	13.7016
	Hamburg				-0.0514	-0.0477	0.1371	0.1468
	Hessen				**-0.6435*** **	**-0.6420*** **	**-0.5561*** **	**-0.5419*** **
	Niedersachsen				**-1.0176*** **	**-1.0155*** **	**-0.9752*** **	**-0.9818*** **
	Nordrhein-Westfalen				-0.1919	-0.1870	-0.1023	-0.1096
	Rheinland-Pfalz				**0.6972** **	**0.6974** **	**0.7266** **	**0.7232** **
	Saarland				-15.3905	-15.4069	-15.1115	-15.1715
	Sachsen				-14.1163	-14.1129	-14.0202	-14.0201
	Sachsen-Anhalt				-15.7942	-15.7913	-15.7862	-15.8184
	Schleswig-Holstein				0.1084	0.1145	0.3521	0.3616
	Thuringen				13.4346	13.4387	13.532	13.5357
7	**UK**				**2.9141*** **	**2.9171*** **	**2.9584*** **	**2.9368*** **
	France				1.3829	1.3863	1.6075	1.6085
	Japan				0.6943	0.6993	0.9724	0.9738
	Netherlands				**-0.8310*** **	**-0.8308*** **	**-0.6123*** **	**-0.6184*** **
	Belgium				**-0.6864*** **	**-0.6839*** **	**-0.4094* **	**-0.4099* **
	Switzerland				**0.4071*** **	**0.4083*** **	**0.2639* **	**0.2632* **
	Sweden				14.0953	14.1039	14.4225	14.4527
	Psuedo R2	0.0092	0.0272	0.0339	0.1383	0.1384	0.1383	0.1315
	Degree of Freedom	1	2	3	25	26	25	26
	Model chi-square (2479 obs)	17.2124***	50.9514***	63.5979***	270.8003***	270.8868***	254.3262***	256.7817***

Notes: 1. * p < 0.10; ** p < 0.05; *** p < 0.001.
2. Predicting the probability of Inter-Organizational knowledge sourcing
3. Reference group for 'Indsutry' is 'industry = 4' - the Chemical industry; Reference group for 'Region' is 'Region = Baden-Wurttemberg'; Reference group for 'Home Country' is 'Home Country = USA'