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Does Spatial Ambidexterity Pay Off?

On the benefits of geographic proximity between technology exploitation and exploration

***** Pre-print version ******

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Abstract

While most scholars tend to agree that it is worthwhile for firms to strive for ambidexterity, less consensus exists on how to organize simultaneously for exploration and exploitation. Although firms increasingly conduct R&D activities in multiple locations and countries, prior ambidexterity research has ignored a geographical dimension in explaining the ambidexterity-performance relationship. In this article, we develop and validate the concept of 'spatial ambidexterity' which we define as the degree to which firms pursue technology exploration and exploitation in proximate locations. We argue that both activities benefit from proximity as firms will increase their ability to enact cross fertilization opportunities and synergies between explorative and exploitative technological activities. Relying on a panel dataset (1995-2003) of the technological activities of 156 large R&D intensive European, US and Japanese firms, we examine the degree to which technology exploration and exploitation activities are pursued simultaneously in similar or different geographical regions. Patent data are used to construct indicators of technology exploration and exploitation activities. Spatial ambidexterity is measured as the degree to which global technology exploration and exploitation activities are pursued in proximity. Our analysis confirms that firms exhibiting greater geographic proximity between technology exploration and exploitation activities display an elevated level of technological performance. Both technology activities of an explorative and exploitative nature appear to benefit from spatial proximity.

Practitioner Points

- Successful ambidextrous firms pay attention to coordination and integration mechanisms between (technology) exploration and exploitation activities
- Spatial proximity facilitates spillovers and synergies between (technology) exploration and exploitation activities
- When firms make decisions on the organizational set-up of (technology) exploration and exploitation activities spatial proximity should be taken into account

Introduction

Innovating firms engage in both technology exploitation and exploration in order to be effective in the short run and to survive and prosper in the long run (Benner & Tushman, 2003; Gupta, Smith, & Shalley, 2006; Lavie, Kang, & Rosenkopf, 2011; March, 1991). Technology exploitation refers to the refinement and extension of existing technologies, leading to predictable, short-term returns. Technology exploration refers to experimentation with new technologies, implying more uncertain returns unfolding over longer timeframes (Levinthal and March, 1993). Scholars advanced the concept of organizational ambidexterity as a firm's ability to engage (effectively) in both (technology) exploitation and exploration (e.g. Gibson & Birkinshaw, 2004; Tushman & O'Reilly, 1996).

Organizational ambidexterity remains a challenge for firms: Exploitation and exploration compete for scarce corporate resources, have distinct objectives, and imply different activities, cultures, processes and organizational routines. Whereas flexible, organic structures are preferred for exploration purposes, efficiency-oriented, mechanistic organizational practices are better suited for exploitation activities (Burns and Stalker, 1961; Abernathy, 1991; Ghemawat et al., 1993; Benner and Tushman, 2003; Jansen et al., 2006; Stettner and Lavie, 2014).

While some scholars (most notably Gibson and Birkinshaw, 2004) suggest that a firm can balance exploration and exploitation within a single organizational unit by building a context that is simultaneously challenging and supportive, other scholars call for a separation of both activities across different organizational units (Jansen et al., 2010; O'Reilly and Tushman, 2004) or even across the boundaries of the firm by engaging in alliances and acquisitions (Stettner and Lavie, 2014). This separation allows for the installment of processes, routines and cultures that are aligned with the specific needs of exploration and exploitation (O'Reilly and Tushman, 2004).

However, the structural separation of technology exploration and exploitation can jeopardize cross-fertilization and synergies between the two activities (Van Looy, Martens, & Debackere, 2005). It has therefore been argued that firms have to complement the separation of exploration and exploitation activities with subtle ways of integrating and/or coordinating both activities. The literature has focused in this respect on the potentially facilitating role of senior management teams and unit-spanning task forces to identify and enact possible synergies between exploration and exploitation activities (O'Reilly and Tushman, 2004; Jansen et al., 2010; Tushman et al., 2010).

In this article, we contribute to the literature on organizing for organizational ambidexterity by arguing that the potential to coordinate between exploration and exploitation activities also depends on the spatial configuration of firms' technology exploration and exploitation activities. More specifically, we introduce the concept of *spatial ambidexterity* as the extent to which firms jointly pursuit technology exploration and exploitation in spatial proximity. With the increasing internationalization of R&D activities by multinational firms, the spatial dimension of the organization of R&D has received recent ample attention (e.g. Lahiri, 2010; Belderbos et al., 2015; OECD, 2007) but the consequences for ambidexterity have not been examined. We argue that spatially ambidextrous organizational structures provide better opportunities for firms to create linkages and synergies between technology exploration and exploitation activities, as knowledge exchange and knowledge creation processes benefit from the geographic proximity of individuals who engage in either exploration or exploitation activities.

We examine the role of spatial ambidexterity by relying on a panel dataset (1995-2003) on the technological activities of 156 large European, US and Japanese firms that are active in five R&D intensive manufacturing industries. Patent data are used to construct indicators of technology exploration and exploitation and to derive information on the locations where technological activities occur. Spatial ambidexterity is measured as the degree to which technology exploration and exploitation activities are pursued within similar regions. The analysis includes regions spanning the major locations of technological activities in the world (US states, European NUTS3 regions, Japanese prefectures and Chinese provinces). Empirical findings suggest that firms adopting spatial ambidextrous organizational structures exhibit elevated levels of technological performance. Both explorative and exploitative technological activities benefit from spatial proximity. Our study thus reveals the importance of the - hitherto neglected - spatial dimension when organizing for organizational ambidexterity.

The next section discusses the background literature and provides the argumentation for our hypothesis on spatial ambidexterity. The third section discusses the methodology and the data, and is followed by the empirical results. The final section discusses the key findings and the managerial and theoretical implications of the study, and concludes with limitations and avenues for future research.

Background Literature and Hypothesis

The concepts of exploration and exploitation have their roots in organizational learning theory and became prominent themes in the innovation literature since the seminal article of March (1991). Technology exploitation refers to the refinement and extension of existing technologies and implies activities like refinement, selection and implementation. Technology exploration refers to the creation of new technologies and implies activities such as search, discovery and experimentation (March, 1991; Gupta et al., 2006). According to March (1991), exploration and exploitation are distinctive activities and firms should devote attention and resources to both. Organizations that engage only in exploration are likely to end up with too many undeveloped ideas and few distinctive competences (Levinthal and March, 1993). Conversely, firms that focus exclusively on exploitation might end up in competency traps (Levitt and March, 1988; Levinthal and March, 1993) and might experience that core capabilities (Prahalad and Hamel, 1990) turn into core rigidities (Leonard-Barton, 1992) when they face competence destroying changes.

Inspired by Duncan (1976), Tushman and O'Reilly (1996) advanced the concept of organizational ambidexterity as a firm's ability to engage in both exploitation and exploration (effectively). Several empirical studies have demonstrated the value of organizational ambidexterity for firms. Using survey data on a sample of 206 firms, He and Wong (2004) showed that maintaining a balance between explorative and exploitative innovation activities is positively related to sales growth. Using, respectively, data on corporate press coverage and patents, Uotila et al. (2009) and Belderbos et al. (2010) found evidence for an inverted u-shaped relationship between the relative emphasis of firms on exploration versus exploitation and their (long-term) financial performance. Hence, firms that balance their attention between exploration and exploitation activities outperform their more focused counterparts that focus more exclusively on exploration or exploitation.

The optimal balance between exploration and exploitation differs across firms and depends on the characteristics of the external environment that firms face (March and Levinthal, 1993). In dynamic environments, characterized by frequent changes in technologies, customer preferences and product demand, current technologies may become obsolete and firms need to invest more in exploratory innovations (Jansen et al., 2006; Uotila et al., 2009). In contrary, when firms operate in competitive environments with strong pressures for efficiency increases and price reductions, it is importance to invest more in exploitative innovations (Jansen et al., 2006).

Organizational scholars have stated that exploration and exploitation activities require different mindsets, processes and working routines to be effective (Tushman and O'Reilly, 2004; Stettner and Lavie, 2014). Exploration benefits from high levels of autonomy, flexible routines and risk taking. The opposite is true for exploitation which is more productive under conditions of predictability, centralization of control and formalized routines (Benner and Tushman, 2003; Jansen et al., 2006; McGrath, 2001). These different requirements complicate the joint pursuit of exploration and exploitation activities within firms (Tushman and O'Reilly, 1996).

While there is broad agreement on the need for organizational ambidexterity, there is considerably less clarity on how firms should organize to achieve this balance (Gupta et al., 2006). A popular view in the literature is that exploration and exploitation activities should be separated due to their conflicting requirements. Some scholars suggest to implement a temporal separation in which a firms shift between periods of exploration and exploitation. For instance, Brown and Eisenhardt (1997) demonstrated in their study of small electronics firms that firms use rhythmic switching to cycle through periods of exploration and exploitation. Relying on a simulation study, Siggelkow and Levinthal (2003) suggest that the temporal sequencing of organizational structures between exploration and exploitation can be an adequate way of organizing. However, while temporal separation may work well for small organizations, it may be less relevant for large firms that are typically active in multiple businesses and manage diverse technology portfolios (Leten, Belderbos and Van Looy, 2007) reflecting different technology lifecycle dynamics and needs for exploration or exploitation (Tushman and O'Reilly, 1996).

A second solution that has been put forward in the literature implies separating exploration and exploitation activities by situating them in different organizational units (Tushman and O'Reilly, 2004; Jansen et al., 2010; Fang, Lee and Schilling, 2010) or even outside the boundaries of the firm by engaging in alliances and acquisitions (Stettner and Lavie, 2014). Studying the development of 22 explorative innovations in 13 different business units, Tushman et al. (2010) found that firms frequently organize explorative innovations in separate organizational units.

Scholars that advocated the use of structural separation mechanisms (Tushman and O'Reilly, 1996 & 2004; Jansen et al., 2010) have at the same time pointed at the importance of integration mechanisms to create synergies between exploration and exploitation activities. Jansen et al. (2010) found that the relationship between structural separation and organizational ambidexterity is mediated by senior team and organizational integration mechanisms, such as the use of task forces that bring together employees from exploration and exploitation units. The simulation study of Fang et al. (2010) suggests that firms can achieve the highest performance when exploration and exploitation occur in small semi-autonomous subunits with a moderate level of cross-group linking.

Whereas firms increasingly disperse their technology development activities around the globe (OECD, 2007; UNCTAD, 2005), existing ambidexterity studies have not taken into account the spatial configuration of firms' technology exploration and exploitation activities and its implications for firms' performance. In the next section, we provide an argumentation why it is important to consider the spatial dimension of exploration and exploitation activities. More specifically, we will introduce the concept of spatial ambidexterity and argue that firms can increase their technological performance by pursuing technology exploration and exploitation activities that are situated close to each other.

The Rationale for Spatial Ambidexterity

Firms are increasingly organizing technology exploration and exploitation activities in multiple geographical regions and countries (Moncada-Paterno-Castello, Vivarelli, & Voigt, 2011), with potential consequences for the joint pursuit of exploration and exploitation. This spatial dimension of ambidexterity has thus far not been studied and can bring valuable insights as to how a firm's exploration and exploitation activities should be organized to improve innovation performance. Drawing on arguments from the literature on organizational learning and innovation management, we expect that firms can increase their technological performance by adopting spatial ambidextrous organizational structures: i.e. organizational arrangements whereby technology exploration and exploitation are pursued in geographic proximity.

As highlighted above, the success of ambidextrous organizations depends on the extent to which firms are able to cross-fertilize and create synergies between exploration and exploitation activities (Van Looy et al., 2005). The presence of a variety of technology activities might provide the foundations and tools that enable inspiration as well as efficiency (Adler, Goldoftas, & Levine, 1999; Zollo & Winter, 2002). Hargadon (1998) proposed in this respect a theory of innovation through knowledge brokering, referring to the process of (re)combining existing knowledge elements into new knowledge. The development of new knowledge might benefit from knowledge that is already available in a firm, and vice versa: existing knowledge and resources can be combined into new capabilities, and new knowledge and resources can strengthen existing competencies (Cao, Gedajlovic, & Zhang, 2009).

More specifically, firms that manage to create linkages between exploration and exploitation activities may benefit from economies of scale and scope when developing technology. Scale economies result from the sharing of infrastructure, laboratories, IT systems, and specialized employees (Fung, 2002) across exploration and exploitation activities. Economies of scope refer to synergies in technology development resulting from engagement in the development activities across a range of technologies (Leten, Belderbos and Van Looy, 2007). The resulting variety enables innovation through 'technology fusion', i.e. combining and fusing knowledge originating from diverse knowledge domains (Kodama, 1992). Innovations that span technological boundaries are found to be, on average, of a higher (technical) value (Rosenkopf and Nerkar, 2001; Nerkar and Roberts, 2004; Phene et al., 2006; Ahuja and Lampert, 2001).

While the establishment of linkages and the search for synergies between exploration and exploitation activities can be stimulated and orchestrated by senior management teams and cross-unit task forces (Tushman and O'Reilly, 2004; Jansen et al., 2010), the actual exchange of knowledge and the engagement in joint technology efforts resides in the interactions of corporate scientists and engineers involved in either technology exploration or exploitation. Such collaboration and knowledge exchange is facilitated by spatial proximity.

Knowledge exchange and collaboration between scientists and engineers is easier in spatial ambidextrous firms where exploration and exploitation are undertaken in close geographic proximity. A key reason is that some, and often the most valuable parts, of knowledge are difficult to articulate and hence 'tacit' or 'sticky' in nature (Polanyi, 1966; Nelson and Winter, 1982; von

Hippel, 1994). Tacit knowledge resides in the heads and practices of scientists and engineers engaged in its production (von Hippel, 1994) and require rich knowledge transfer channels, like direct, face-to-face interactions that are promoted by geographical proximity (Nonaka, 1994; Leten, Landoni and Van Looy, 2014). Furthermore, geographic proximity may increase chances for serendipitous encounters between corporate scientists and engineers that focus on either exploration or exploitation activities (Allen, 1977). These meetings may be an important source of inspiration and ultimately synergies in technology development for firms.

Combined, these observations and arguments suggest that firms may benefit from organizing explorative and exploitative technology activities in spatial proximity to each other.

Hypothesis: Spatial ambidexterity (a higher degree of spatial proximity between a firm's technology exploration and exploitation activities) is positively associated with technological performance.

Methodology and Data

Sample and Data Collection

The relationship between spatial ambidexterity and the technological performance of firms is investigated using a panel dataset (1995-2003) on the technological activities of 156 sample firms. The sample firms are R&D-intensive European, US and Japanese firms in five industries: (i) non-electrical machinery, (ii) pharmaceuticals & biotechnology; (iii) chemicals; (iv) IT hardware (computers and communication equipment); and (v) electronics & electrical machinery. The firms are drawn from the 2004 EU industrial R&D investment scoreboard, which provides listings of the 500 most R&D-intensive European, and 500 most R&D-intensive US and Japanese firms across all industries. This resulted in an initial sample of 186 firms. Subsequently, we limited the sample to those 156 firms that engage in both technology exploration and exploitation in the observation period. This gives us a maximum number of 1404 (i.e. 156 times 9) observations. Since spatial ambidexterity can only be measured when a firm engages in both exploration and exploitation in a certain year, the actual number of observations in the regressions is reduced to 1132 (as we didn't observe exploration for a number of year/firm observations). The selected firms are the top R&D spenders in their region of origin and industry. The sample contains around the same number of firms in each industry for each country of origin (Table 1). Whereas the sample firms have their headquarters in 13 countries, technological (invention) activities occur in up to 29 countries and up to 158 different regions on a yearly basis.

Insert Table 1 about here

Patent data from the European Patent Office (EPO) are used to construct indicators of firms' technological activities (exploration and exploitation) at the consolidated level: all patents of the parent firm and its consolidated (majority-owned) subsidiaries. We used lists of subsidiaries included in corporate annual reports, 10-K reports filed with the SEC in the US and, for Japanese firms, information on foreign subsidiaries published by Toyo Keizai in the yearly 'Directories of Japanese Overseas Investments' to establish consolidated corporate groups. As changes can occur in a firm's group structure, the consolidation is conducted on an annual basis (1995-2003). We opt for patent application data (rather than grants) as applications provide a better indication of technological activities of a more explorative nature. Data from the European Patent Office (EPO) are preferred to data from the United States Patent and Trademark Office (USPTO) as EPO patents are considered to provide a better indication of valuable technological activities. This is because the cost of patenting is two to five times greater at EPO than at USPTO, the workload of patent examiners is four times smaller at EPO, and EPO has a 20-30% lower patent-granting rate than USPTO (Jaffe & Lerner, 2004; Quillen & Webster, 2001; Van Pottelsberghe de la Potterie & François, 2006).

Dependent Variable

The main dependent variable in this study is the annual (1996-2003) technological performance of a firm (*Technological performance*), measured by the number of patent applications weighted by their forward citations. Patent counts weighted by citations overcome the limitations of simple counts by taking into account the value of innovations (Trajtenberg, 1990). Patent citation counts are constructed based on a fixed time window of eight years after the patent's application date, as most patents receive the bulk of citations after a period of eight years. The dependent variable (technological performance) is a count variable. We therefore rely on count data models as they take into account the non-negativity and discreteness of the dependent variable (Cameron and Trivedi, 1998). We use Negative Binomial count data models that control for over-dispersion in the dependent variable. We employ fixed-effects estimations to control for unobserved firm level heterogeneity that may affect technological performance.

In order to measure whether firms adopt spatial ambidextrous organizational structures, we classify the total number of patent applications into two groups: exploratory and exploitative patents. Technology class information is used to make a distinction between explorative and exploitative patents. The EPO classifies all patents into at least one technology field, using the International Patent Classification System (IPC). The IPC system classifies the technology landscape into 628 IPC-4 digit classes (used in the study) and several ten-thousands of subclasses nested within these classes. In line with Belderbos et al. (2010), a patent is defined as explorative when it is situated in a technology field that is new or unfamiliar to the firm. A technology field is considered as new to a firm in year t, if the firm did not patent in the technology field in the past five years (t-5 to t-1). Due to the often fast transformation of technological knowledge, a five-year window is chosen to evaluate experience with technology fields (Ahuja & Lampert, 2001; Hall, Jaffe, & Trajtenberg, 2005; Leten, Belderbos, & Van Looy, 2007). Because a technology field is likely to remain relatively new and unexplored for the firm immediately after the firm becomes involved in it, a technology field keeps its explorative rating for a period of three successive years.

In total, 187,292 patent applications (belonging to the 156 sample firms for the period 1995-2003) are classified as explorative or exploitative. The patent data are used to construct the relevant variables related to exploitation, exploration and innovation performance at the firm level. The majority of patents are classified as exploitation (92%), and hence the remainder obtain the status of exploration (8%). The average share of exploration patents at the firm-level (calculated for the panel of 1132 observations in the regression models) is 19%. The median value of this variable is 0.14 (14%) and it ranges between 0.01 and 0.92 across sample observations.

Spatial Ambidexterity

Spatial ambidexterity is measured as the degree to which technology exploration and exploitation activities of a firm are pursued globally within similar regions. To identify the location(s) where explorative and exploitative technological activities have been conducted, we rely on inventor address information on explorative and exploitative patents. Allocation based on inventor addresses is the most commonly used approach in patent studies since – especially for large firms – allocation based on assignee addresses might reveal the location of corporate headquarters rather than the actual place where technological activity, resulting in a patent, took place (Deyle & Grupp, 2005; Khan & Dernis, 2006). Locations of firms' R&D activities are identified at the level of regions that are roughly comparable in population size: US states, Japanese prefectures, Chinese provinces and NUTS3 regions in Europe. On a yearly base, our sample firms on average pursue technological activities in 19 different regions around the world.

We create for each firm and year two vectors that represent the distribution of respectively the exploration and exploitation patents over the different geographical regions. The degree of spatial ambidexterity of a firm is measured by calculating the cosine between the exploration and exploitation vectors.[i] Specifically, the cosine index S_{ij} measures the angular separation between the vectors representing the exploration (*i*) and exploitation (*j*) activities within all the locations (k) where a firm pursued technological activity that resulted in patents:

$$S_{ij} = \frac{\sum_{k=1} C_{ik} * C_{jk}}{\sqrt{\sum_{k=1} C^2{}_{ik}} * \sqrt{\sum_{k=1} C^2{}_{jk}}}$$

S_{ij} takes larger values if a firm pursues exploratory and exploitative inventive activities within the same locations. It is equal to one for pairs of exploratory and exploitative activities with an identical locational distribution, while it goes to zero for pairs of exploratory and exploitative activities in locations that do not overlap. In other words, a value close to 1 indicates a high degree of spatial ambidexterity. The measure of spatial ambidexterity is lagged with one year in the regressions to allow for a time lag between a firm's organizational structure and the output (patents) of R&D activities. The short time lag of one year is consistent with the findings of Hall *et al.* (1983) who found evidence for a time lag of one year between R&D investments and patents.

Control Variables

The study's empirical models control for other factors that are likely to impact firms' technological performance. All variables are one-year lagged. The models also include seven time dummies to account for time specific factors affecting the number of patent applications.

R&D expenses. Firms that invest more in R&D are expected to generate more patentable inventions (Pakes & Griliches, 1984). We control for one-year lagged logarithmically transformed R&D expenditures of the firm, measured in constant U.S. dollars (millions). The data on R&D expenditures are collected from corporate annual reports, Worldscope, and Compustat. We create a proxy for the R&D expenditures related to exploratory inventive activities (*R&D expenditures exploration*) by multiplying the total R&D expenditures of a firm with its exploration share in patents. The R&D expenditures for exploitative inventive activities (*R&D expenditures exploitation*) of a firm are calculated in a similar way. In line with total R&D expenditures, both of these variables are logarithmically transformed.

Patent Propensity. Patent propensity is measured as the ratio of patents to R&D expenditures. This variable controls for differences across firms in their propensity to apply for patents. In parallel with R&D expenditures, we also create separate variables for the patent propensity related to technology exploration (*patent propensity exploration*) and exploitation (*patent propensity exploitation*). These variables are constructed as the ratio of exploration (exploitation) patents and exploration (exploitation) to R&D expenditures.

Technological diversification. Firms that have a more diversified technology portfolio can benefit from economies of scope and knowledge spillovers in technology development (Leten et al., 2007; Quintana-Garcia & Benavides-Velasco, 2008). The analysis therefore controls for the level of technological diversification, defined as the spread of a firm's patents over technology fields (measured by IPC 4-digit classes on patents). In line with Leten et al. (2007) and Quintana-Garcia and Benavides-Velasco (2008) we employ a number equivalent index, which is the inverse of the Herfindahl index of concentration. Let N_i denote the number of patents of a certain firm that belong to technology field i, such that $N = \sum_i N_i$, then technological diversification is calculated as $1 / (\sum_i (N_i/N)^2)$. The technological diversification index takes higher values if firms are active in more technology fields and have spread their competencies more equally across these fields. We include both the linear and quadratic terms of technological diversification in our models to allow for possible negative effects of excessive technological diversification (Leten et al., 2007).

Geographic diversification. We also control for the geographic diversification of firms' technological activities. Firms that spread their R&D activities over multiple countries get access to geographically dispersed pockets of scientific and technological expertise and local customers, which may provide insights for the development of new inventions (Belderbos et al., 2015; Penner-Hahn & Shaver, 2005; Todo & Shimizutani, 2008). Geographic diversification is measured as the inverse of the Herfindahl index of concentration of a firm's patents over countries.

Exploration orientation. Even though all sample firms engage in both exploration and exploitation, there are important firm-level differences in the emphasis that is placed on technology exploration. The exploration orientation of a firm indicates the relative importance that it attaches to exploration (Heyden et al., 2015; Uotila et al., 2009) and is measured as the share of exploration patents in the total patents. Firms that have a higher exploration orientation may exhibit a lower (short-term) technological performance since exploration activities are characterized by high levels of uncertainty and higher failure rates (March, 1991; Mitchell & Singh, 1992).

Empirical Results

The descriptive statistics and correlations between the dependent and independent variables used in this study are shown in table 2. There is a positive and significant correlation (0.22) between spatial ambidexterity and firm's technological performance. There are no excessively high correlations between the variables that are used simultaneously in the same models.

Insert Tables 2 & 3 about here

Table 3 shows the results of the fixed-effects negative binomial regression analyses in which we test our central hypothesis that firms adopting spatial ambidextrous structures exhibit an elevated technological performance. Model 1 only includes the control variables and shows that both R&D expenditures and patent propensity are positively and significantly related to technological performance. Technological diversification has an inverted U-shaped relationship with technological performance as evidenced by the positive and significant linear term and the negative and significant quadratic term. The top of the inverted U-curve is reached at the value of 25, which is lower than the maximum sample value of 59. We observe a significantly negative effect of exploration orientation but no significant effect of geographic diversification.

In model 2, we add the spatial ambidexterity variable. As shown by the log likelihood ratio test (model 2 vs. model 1) adding this variable increases the model fit. The coefficient of spatial ambidexterity is positive and significant. This confirms our hypothesis: Spatial ambidexterity (a higher degree of spatial proximity between a firm's technology exploration and exploitation activities) is positively associated with technological performance.

We conducted additional analysis to examine whether spatial ambidexterity has differential effects on the exploration and exploitation performance of firms. These results are reported in models 3-4 (exploration performance) and 5-6 (exploitation performance). Most of the control variables have a similar effect as in the analysis of total technological performance. The only difference is the insignificance of R&D expenditures in the exploration analysis. A possible explanation is that we rely on a proxy due to a lack of actual data on exploration R&D expenditures. Adding spatial ambidexterity to the exploitation and exploration models again increases the model fit as evidenced by the log likelihood ratio tests. The coefficient of spatial ambidexterity is positive and significant in both the exploration and exploitation models, with similar coefficient sizes and with the significance level the highest in the exploitation model. Both technology exploration and exploitation activities appear to benefit from the organization of exploration and exploitation in spatial proximity.

Conclusion and Discussion

While extant literature agrees that organizational ambidexterity is an objective worthwhile to pursue, how firms should organize explorative and exploitative efforts effectively remains subject to scholarly debate. In this article, we develop and validate the concept of 'spatial ambidexterity' which we define as the simultaneous pursuit of technology exploitation and exploration activities in geographic proximity. Utilizing a panel dataset (1995-2003) of 156 large European, US and Japanese R&D intensive firms, we examine the impact on firms' technological performance of the degree to which exploration and exploitation are pursued in similar or different geographical regions in the world. Our findings reveal that spatial ambidextrous organizational structures pay off in terms of technological performance.

When distinguishing between technological performance of an exploitative nature and technological performance of an exploratory nature, our analysis shows that both types of technology activities benefit from spatial proximity to each other. Hence, while a number of scholars assert that exploitation may provide the foundations and tools that enable exploration (Adler et al., 1999; Zollo & Winter, 2002), our analysis suggest that exploitation also benefits from (proximity to) exploration. Apparently, the nearby presence of exploration introduces technological novelty that may also be beneficial to rejuvenate the larger and mature part of the firm's technology portfolio represented by exploitation activities.

Theoretical Implications

Previous research has presented a range of organizational solutions to achieve a balance between exploitation and exploration (O'Reilly and Tushman, 2013). These include structural separation, temporal cycling through periods of exploration and exploitation, building an organizational context in which teams or individuals are motivated to divide their time between exploration and exploitation, and engaging in inter-firm activities such as alliances and acquisitions. Although firms increasingly organize their exploratory and exploitative activities in a geographically dispersed manner, prior ambidexterity research has ignored the geographical dimension when modelling the ambidexterity-performance relationship. This is surprising, as existing research on international knowledge sourcing has pointed at its relevance (e.g. Alcacer & Chung, 2007; Ko & Liu, 2015; Rosenkopf & Almeida, 2003). This literature stream suggests that geographical proximity enables knowledge spillovers in local innovation systems, which in turn facilitates learning and may result in a higher degree of technological performance. Firms may not only benefit from inter-organizational spillovers, but also from intra-organizational spillovers between exploration and exploitation activities that are performed in geographic proximity.

Our study contributes by examining the performance impact of the degree to which technology exploration and exploitation activities are pursued in spatial proximity. Our findings underscore the relevance of including a geographic dimension in the analysis to better understand how firms can reach an effective balance between both technology activities. Indeed, where previous contributions stressed the importance of achieving integration via the role and behavior of senior management and cross-unit task forces (e.g. O'Reilly & Tushman, 2004 & 2011; Jansen et al., 2010); our findings point to a complementary, bottom–up, mechanism – localized intra-firm knowledge transfers and spillovers – to achieve synergies between exploitation and exploration. As achieving synergies is likely to be key in order for ambidexterity to become sustainable (Van Looy et al., 2005), future conceptualizations of organizational structures to support ambidexterity might benefit from paying sufficient attention to integrative mechanisms, including spatial proximity of exploration and exploitation.

Managerial Implications

Our findings might enable managers to assess whether their current technological performance can be improved by considering the geographical dispersion of their firms' exploratory and exploitative activities. While it is clear that firms already enact geographical dimensions of organizing, our findings can inform the decision making process on firms' existing and future organizational set-up of exploration and exploitation by highlighting the importance of spatial proximity between technology exploration and exploitative activities. An illustrative example is the development of the Nespresso coffee system in the late 1980s and early 1990s, by the Nestlé company. To develop, produce and market the new Nespresso system, Nestlé created a separate 100%-owned Nestlé affiliate called Nespresso, but located it across the street from the main Nestlé organization (Markides and Oyon, 2010; Miller and Kashani, 2003). Whereas the structural separation allowed for the installment of different processes, cultures and mindsets, the spatial proximity allowed Nestlé to enact synergies between the traditional Nescafé and the new Nespresso coffee businesses.

It goes without saying that benefits stemming from internal spillovers and knowledge transfers between technology exploration and exploitation activities need to be considered in conjunction with benefits arising from locating (new) development activities in regions with specific expertise that may be new to the firm (Lecocq et al., 2011; Belderbos et al. 2014). Managers are also well advised to consider that technology relatedness (Breschi, 2003; Leten et al., 2007 & 2016) can play an important role in effective entry and performance in new technology fields. Explicit considerations of these factors will result in more informed and hence more effective corporate decision making regarding the composition and location of exploratory and exploitative R&D activities.

Limitations and avenues for future research

Our research is subject to limitations. We highlight four particular issues that may inspire future research. First, our analysis of spatial ambidexterity has focused on ambidexterity in technology development. Technology development is an important aspect of ambidextrous organizing and firms' sustainable competitive advantage, and it is well conceivable that the benefits of cross-fertilization and knowledge exchange in relationship with spatial proximity are most pronounced for firms' technological activities. We suggest that future research employs broader conceptualizations of ambidexterity with exploitation and exploration activities extending to non-technological activities such as marketing, in order to investigate to what extent our findings can be replicated in such settings.

Second, this article examined the importance of spatial ambidexterity using data for the period 1995-2003. Although we think that the relationship between spatial ambidexterity and firms' technological performance is generic and not strongly depended on the time period under study, we consider it an useful avenue for further research to examine whether the effect of spatial ambidexterity has strengthened or weakened in more recent time periods.

Third, our findings are based on data for large R&D intensive firms and cannot be easily generalized to small firms, which often achieve ambidexterity by alternating between focused periods of exploration and exploitation (Brown and Eisenhardt, 1997).

Fourth, our research has focused on the role of spatial proximity but did not examine the role of other types of organizational configurations, in particular the degree of structural separation between exploitation and exploration within or across regions, and inter-organizational configurations that might reflect patterns of ambidexterity as well. Efforts to address these dimensions would benefit from the availability of fine-grained data regarding organizational structures and R&D alliances. Our current data compile technological activities without differentiating between organizational units of the firm in a region and the role that for instance mergers and acquisitions and technology alliances play in the changing configuration of exploitation and exploration. Extending analysis in these directions may imply the introduction of survey efforts (to measure organizational structures) and the combination of multiple databases that contain information on patents, mergers and acquisitions and technology alliances. The build-up of such data platforms would allow researchers to examine the interplay of different separation and integration mechanisms and to identify the optimal organizational configurations for reaching organizational ambidexterity.

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Table 1. Sample Firm Distribution by Industry and Region of Origin

Industry	Europe	United States	Japan
Chemicals	12	10	10
Pharmaceuticals and Biotechnology	10	13	8
Engineering and General Machinery	11	9	9
IT hardware	11	14	12
Electronics and Electrical Machinery	7	6	14
Total	51	52	53

Table 2. Descriptive Statistics and Correlations

	Variables	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
1.	Technological performance	1598.82	2901.36	0	20225												
2.	Exploration performance	109.78	187.43	0	3272	0.49**											
3.	Exploitation performance	1489.04	2813.88	0	19830	0.99**	0.44**										
4.	Spatial ambidexterity	0.72	0.29	0	1	0.22**	0.18**	0.21**									
5.	R&D expenditures (logged)	12.52	1.37	8.44	15.63	0.64**	0.31**	0.64**	0.19**								
6.	R&D expenditures exploration (logged)	10.42	1.07	6.95	14.53	0.35**	0.36**	0.34**	0.14**	0.67**							
7.	R&D expenditures exploitation (logged)	12.27	1.53	7.91	15.61	0.63**	0.29**	0.64**	0.21**	0.98**	0.56**						
8.	Patent propensity	0.32	0.31	0	2.84	0.05+	0.05+	0.05+	0.14**	-0.36**	-0.48**	-0.30**					
9.	Patent propensity exploration	0.38	0.63	0	13.37	0.01	0.05+	0.01	0.02	-0.24**	-0.48**	-0.18**	0.58**				
10.	Patent propensity exploitation	0.33	0.33	0	3.11	0.04	0.03	0.04	0.11	-0.37**	-0.42**	-0.35**	0.95**	0.47**			
11.	Technological diversification	11.01	7.9	1.26	59.39	0.34**	0.22**	0.34**	0.17**	0.34**	0.36**	0.33**	0.10**	-0.02	0.09**		
12.	Exploration orientation	0.19	0.18	0.01	0.92	-0.35**	-0.04	-0.36**	-0.18**	-0.50**	0.19**	-0.65**	-0.08**	-0.16**	0.05*	-0.10**	
13.	Geographic diversification	1.73	0.91	1	5.8	-0.02	-0.11**	-0.02	-0.29**	-0.02	-0.12**	-0.01	0.09**	0.07*	0.09**	0.01	-0.06*

Remarks: + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Table 3. Results of Negative Binomial Fixed Effects Panel Data Analysis of Technological Performance

	Technological Performance				Exploration Performance				Exploitation Performance			
Variables	**Model 1**		**Model 2**		**Model 3**		**Model 4**		**Model 5**		**Model 6**	
Spatial ambidexterity			0.157**	(0.056)			0.175+	(0.098)			0.181**	(0.060)
R&D expenditures	0.224**	(0.031)	0.226**	(0.031)								
R&D expenditures exploration					0.049	(0.032)	0.046	(0.032)				
R&D expenditures exploitation									0.431**	(0.025)	0.429**	(0.025)
Patent propensity	1.027**	(0.045)	1.022**	(0.045)								
Patent propensity exploration					0.212**	(0.019)	0.211**	(0.019)				
Patent propensity exploitation									1.037**	(0.042)	1.034**	(0.042)
Technological diversification	0.051**	(0.006)	0.049**	(0.006)	0.096**	(0.011)	0.095**	(0.011)	0.045**	(0.006)	0.042**	(0.006)
Technological diversification^2	-0.001**	(0.000)	-0.001**	(0.000)	-0.001**	(0.000)	-0.001**	(0.000)	-0.001**	(0.000)	-0.001**	(0.000)
Exploration orientation	-0.750**	(0.124)	-0.757**	(0.125)								
Geographic diversification	-0.024	(0.030)	-0.012	(0.030)	0.005	(0.043)	0.019	(0.043)	-0.035	(0.032)	-0.021	(0.032)
Year dummies	yes		yes		yes		yes		yes		yes	
Constant	-1.407**	(0.394)	-1.529**	(0.398)	-0.902**	(0.345)	-0.999**	(0.351)	-4.145**	(0.318)	-4.239**	(0.320)
Number of observations	1132		1132		1132		1132		1132		1132	
Log-likelihood value	-6439.140		-6435.197		-4866.817		-4865.197		-6285.178		-6280.466	
Wald chi-square	846.86**		850.20**		313.48**		317.39**		885.02**		892.99**	
LR-test model 2 vs. model 1			7.89**									
LR-test model 4 vs. model 3							3.24+					
LR-test model 6 vs. model 5											9.42**	

Remarks: + p < 0.1, * p < 0.05, ** p < 0.01

[i] Prior work relied on a cosine index to measure the similarity of technology profiles of firms (Jaffe, 1986) or the technological relatedness of technology fields (Breschi *et al.*, 2003).