TECHNOLOGICAL CAPABILITY, STRATEGIC FLEXIBILITY, AND PRODUCT INNOVATION

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This paper examines the role of technological capability in product innovation. Building on the absorptive capacity perspective and organizational inertia theory, the authors propose that technological capability has curvilinear and differential effects on exploitative and explorative innovations. The findings support the proposition that though technological capability fosters exploitation at an accelerating rate, it has an inverted U-shaped relationship with exploration. That is, a high level of technological capability impedes explorative innovation. Strategic flexibility strengthens the positive effects of technological capability on exploration, such that when strategic flexibility is high, greater technological capability is associated with more explorative innovation. Copyright © 2009 John Wiley & Sons, Ltd.

INTRODUCTION

To develop innovation, firms invest heavily in the building of technological capabilities that offer the skills and abilities to deploy and utilize various resources and know-how (Anderson and Tushman, 1990; Song et al., 2005). However, extant literature offers conflicting views regarding whether such capability building leads to more explorative or exploitative innovations. Studies rooted in the absorptive capacity perspective indicate that a distinctive capability may foster a higher level of exploration (Rosenkopf and Nerkar, 2001). When a firm builds its technological capabilities, its absorptive capacity increases, which, in turn, encourages receptivity to external information and explorative innovation (Lavie and Rosenkopf, 2006). In contrast, building on organizational inertia theory (Hannan and Freeman, 1984), some researchers suggest that a higher level of organizational capabilities in a particular field fosters more exploitation in that field (Levinthal and March, 1993). As firms accumulate more experience and become more efficient in employing their existing knowledge, the self-reinforcing nature of learning generates more exploitative activities (Benner and Tushman, 2003). In short, the relationship between technological capability and exploitative versus explorative innovations remains unclear.

We believe that these inconsistencies derive partially from the implicit assumption in previous studies that technological capability has a linear and positive relationship with the two types of innovations, that is, a firm’s engagement in technological development leads to more exploitative or explorative innovations. However, because innovation is the generation and/or acceptance of
ideas and processes that are new to the company (Garcia and Calantone, 2002), innovative activities are bounded by existing processes and routines within the organization. A combinative view of absorptive capacity and organization inertia therefore is necessary to resolve the existing controversy. With the confluence of absorptive capacity and organizational inertia, the relationship between technological capability and exploitation/exploration may be more complicated than previously depicted.

In particular, we propose that the effects of technological capability are not only curvilinear but also differential across exploitation and exploration. Technological capability fosters exploitation at an accelerating rate, whereas it has an inverted U-shaped relationship with exploration. That is, a moderate level of technological capability is optimal for explorative innovation, but a high level of technological capability actually impedes it. Furthermore, we propose that to sustain their exploration, firms with strong technological capabilities must develop dynamic capabilities that enable them to reconfigure their resources and adapt to changing environments (Eisenhardt and Martin, 2000; Teece, Pisano, and Shuen, 1997). Strategic flexibility, as one type of dynamic capability, may help firms better reallocate resources and break down existing operational routines. As a result, strategic flexibility has the potential to strengthen the positive effects of technological capability on exploration and shift a firm’s current frontier of exploration to a higher level.

**THEORY AND HYPOTHESES**

According to March, ‘the essence of exploitation is the refinement and extension of existing competences, technologies, and paradigms [whose] returns are positive, proximate, and predictable [whereas] the essence of exploration is experimentation with new alternatives [whose] returns are uncertain, distant, and often negative’ (March 1991: 85). Applying March’s view to the domain of product innovation, we define exploitation as the use and refinement of existing knowledge and skills in product development, whereas exploration refers to the search and pursuit of completely new knowledge and skills in product development (see also Benner and Tushman, 2003; He and Wong, 2004).

**Absorptive capacity view of product innovation**

Innovation is critical for firms to adapt to turbulent environments and achieve a sustainable competitive advantage. Various theories have attempted to disentangle the drivers of innovation, of which the absorptive capacity perspective is one of the most influential (Zahra and George, 2002). As Cohen and Levinthal (1990: 128, italics added) propose, absorptive capacity, or a firm’s ability to ‘recognize the value of new information, assimilate it, and apply it to commercial ends,’ is pivotal to the firm’s innovative activities. To develop innovation, a firm must first search, identify, and evaluate alternative knowledge from different sources. After identifying potentially useful knowledge, the firm must transfer that knowledge from the source and edit it to make it understandable to the firm. Then, the firm must use and transform the knowledge into specific product designs that constitute product innovation (Carlile, 2004; Smith, Collins, and Clark, 2005).

Absorptive capacity is primarily a function of a firm’s prior related knowledge; a firm’s knowledge base underpins how well it can use new knowledge to achieve desired innovation outcomes (Cohen and Levinthal, 1990). Each firm has its own firm-specific technological resources, such as patents owned, number of technical personnel, or the amount of technical knowledge stores. In particular, technological capability refers to a firm’s ability to employ various technologies (Afuah, 2002). As technological capability gets embedded in organizational routines over time, it becomes more valuable, inimitable, and non-substitutable (Hamel and Prahalad, 1994), and therefore represents an important source of absorptive capacity. Prior research also highlights the critical role of technological capability in innovative activities. For example, Cohen and Levinthal (1990) suggest that technological capability promotes organizational learning and generates product innovations. Moorman and Slotegraaf (1999) find that technological capability not only fosters new product creativity but also facilitates product development speed. Therefore, technological capability plays a central role in product innovation and warrants special examination.
Organizational inertia view of product innovation

Because innovations integrate new ideas and practices into an organization, they are influenced by existing organizational processes and routines. With their distinct characteristics, however, exploitative and explorative innovations require different sets of organizational structures and processes. Exploitation favors mechanic structures to maintain stability and improve efficiency, whereas exploration requires organic structures to increase the amount of experimentation and adaptation (He and Wong, 2004; March, 1991). In this sense, both exploitation and exploration are bounded by the firm’s structure and coordination, and they likely experience different pressures from organizational inertia.

Organizational inertia refers to the stability in products, processes, and policies that underlies the inadequate adaptation to changing environments (Hannan and Freeman, 1984). Organizations often establish organizational routines to maximize the efficiency of their business operations and achieve reliable outcomes. As they become embedded within an organization over time, the routines may elicit automatic responses based on past experience and create strong internal resistance against radical changes (Nelson and Winter, 1982). On the one hand, these constraints represent templates that facilitate and smooth firm operations. On the other hand, these institutionalized routines can generate strong pressures against radical changes from the status quo (Hannan and Freeman, 1984).

Gilbert (2005) further suggests that two types of organizational inertia seriously undermine radical changes: resource and routine. The former refers to inertia in resource allocation patterns, and the latter pertains to inertia in the organizational processes that use the resource investment. In rapidly changing environments, firms may fail to alter the way they allocate resources due to resource dependency (Christensen, 1997) or unwillingness to change (Chandy and Tellis, 1998). Even if they invest, the persistence and inflexibility of firm routines may inhibit support for new resources and adaptations to technological discontinuities (Teece et al., 1997).

To overcome organizational inertia, a high level of flexibility in resource allocation and coordination appears to be imperative. More formally, we define strategic flexibility as the ability of a firm to reallocate and reconfigure its organizational resources, processes, and strategies to deal with environmental changes (Sanchez, 1995). It depends jointly on resource flexibility, which emphasizes the inherent flexibility in resource allocations in pursuing alternative courses of actions, and coordination flexibility, which focuses on flexibility in coordinating the use of firm resources (Gilbert, 2005; Sanchez, 1995). In particular, resource flexibility reflects the range of different products that a firm’s resources can be effectively used to develop, manufacture, distribute, or market. Coordination flexibility represents efforts to synthesize subdivided functions and interests and reconfigure existing organizational routines to support the intended product strategies (Sanchez, 1995). In this respect, strategic flexibility represents one type of dynamic capability that enables firms to address discontinuities in the environment (Eisenhardt and Martin, 2000; Teece et al., 1997).

Taken together, as a firm accumulates more technological capability, its absorptive capacity should increase, which leads to more product innovations. At the same time, increasing levels of technological capability may cause the firm to form a unique set of organizational routines that likely limit its explorative innovation. The confluence of absorptive capacity and organizational inertia may make the relationship between technological capability and innovation more complex, as we examine next.

Technological capability and exploitation

A firm’s technological capability is developed over time and accumulated through its past experience. It reflects the firm’s abilities to employ various technical resources (Afuah, 2002). Levinthal and March (1993) posit that firms with a superior capability in a particular field are more likely to search more local, neighborhood information and elicit their existing knowledge stores to achieve immediate advantage. Benner and Tushman (2003) similarly indicate that process management techniques and skills promote exploitative learning and facilitate incremental innovations. Empirical evidence provides some indirect support for this argument. Rothaermel and Deeds (2004), for example, find that an entrepreneurial venture with strong technological capabilities tends to engage in more exploitation alliances to gain access to complementary assets such as manufacturing and
marketing resources in order to commercialize its new products.

We augment existing literature by suggesting that technological capability may facilitate exploitation at an accelerating rate, such that a unit increase of technological capability relates to increasingly higher levels of exploitative activities. First, the accumulation of technical expertise enables a firm to better understand and recognize the value of technological development in the existing trajectory, which in turn provides insights into how to exploit current knowledge and skills (Cohen and Levinthal, 1990). Second, as the firm accumulates its knowledge in a technological field, it becomes more competent in assimilating external knowledge in similar fields due to the positive feedback between experience and learning. This self-reinforcing nature makes the firm more efficient in integrating additional skills into its existing knowledge base (Levinthal and March, 1993; Lieberman and Montgomery, 1998). Third, applying similar knowledge in existing domains to refine a product is consistent with current organizational processes and routines. Accordingly, a high level of technological capability should facilitate greater exploitation of existing know-how (Stuart and Podolny, 1996). Fourth, the pressure of organizational inertia intensifies as a firm accumulates extensive technological skills and forms its unique processes and routines (Hannan and Freeman, 1984). Such inertia pressure encourages the firm to rely on its existing know-how and engage in search activities that improve efficiency and produce reliable outcome in organizational performance (Lavie and Rosenkopf, 2006). Therefore,

_Hypothesis 1:_ Technological capability has an increasingly positive relationship with exploitation, such that it has (a) a positive linear effect and (b) a positive quadratic effect on exploitation.

**Technological capability and exploration**

When a firm builds its technological capability, it invests substantial resources in research and development (R&D), which involves the discovery of new products, the accumulation of knowledge stores, and the training of technical personnel (Afuah, 2002). The accumulation of technological knowledge increases the firm’s ability to evaluate and use new technologies and skills in product innovation (Zahra and George, 2002). As a result, the firm can quickly identify new technological trends, experiment with emerging designs, and engage in product innovations beyond the current technological boundaries (Rosenkopf and Nerkar, 2001). Therefore, the accumulation of technological capabilities coincides with the process of explorative innovation.

However, we posit that the positive effect of technological capability on exploration may decline after it reaches a high level. First, a firm with strong capabilities in an existing technology domain may be complacent with what it already has achieved, which may cause it to overlook new knowledge that is beyond its current technology trajectory (Cohen and Levinthal, 1990). Second, assimilating new knowledge into an existing knowledge base is difficult for a firm that already has gained substantial experience in a particular technological field. Since totally new knowledge from another field may require a different mindset to process, the firm may need to unlearn what it already possesses to assimilate the new knowledge (Levinthal and March, 1993). The costs associated with learning new knowledge and restructuring existing know-how encourage technology-entrenched firms to rationally lower their explorative behaviors (March, 2006). Third, applying totally new knowledge to commercial ends is even more challenging for firms with strong existing technology bases. Because of the substantial investment in existing technologies and the high risk associated with the choice of a new dominant design, the returns from exploration are far less certain and more distant in time compared to the returns from exploitation. Consistent with this logic, Rothaermel (2001) finds that incumbents in the pharmaceutical industry benefit more from exploiting complementary resources than from exploring new technologies. Fourth, organizational inertia strongly discourages explorative innovations in firms with a well-established, entrenched technology base. Explorative innovation often violates existing systems of organizational routines and requires the support of a new set of processes that may be incompatible with existing ones. As a result, while managers in general might support ‘innovation,’ exploration in fact receives strong resistance in organizations with well-entrenched know-how (Dougherty and
Technological Capability and Product Innovation

Heller, 1994). Therefore, we expect that the level of exploration decreases when a firm gains substantial expertise in a particular technological field. In short, a moderate level of technological capability will be optimal for exploration.

**Hypothesis 2:** Technological capability has an inverted U-shaped relationship with exploration, such that it has (a) a positive linear effect and (b) a negative quadratic effect on exploration.

**Facilitating role of strategic flexibility**

To overcome organizational inertia, strategic flexibility is necessary for firms to break down the institutional routines and sustain their explorative innovations. Because strategic flexibility emphasizes the flexible use of resources and reconfiguration of processes, it reflects one type of dynamic capability that enables firms to achieve a competitive advantage in turbulent markets (Eisenhardt and Martin, 2000; Teece et al., 1997). Developing flexibility in organizational forms, resource management, and manufacturing processes may create an organizational culture that supports explorative innovation (Matthyssens, Pauwels, and Vandenberghem, 2005). However, since strategic flexibility serves as an organizing principle for structuring and coordinating various resources and functional units (Zander and Kogut, 1995), it may not affect a firm’s innovation output by itself. Rather, it may enhance the value of existing technological capabilities in innovations. In this sense, strategic flexibility is one type of complementary organizational capability that can help the firm achieve the full potential of its key resources when used in combination (Barney, 1997; Zhou et al., 2008).

We posit further that strategic flexibility enhances the positive effect of technological capability on exploration. That is, when strategic flexibility is high, strong technological capability leads to more explorative activities. First, strategic flexibility overcomes organizational inertia in firms with a strong technology base. Flexibility in its resource allocations and product designs allows the firm to use new technologies and experiment with different product variations (Worren, Moore, and Cardona, 2002). Flexibility in coordination among business units relaxes routine inertia, which helps the firm break down its institutionalized technological processes and explore new alternatives (Gilbert, 2005). Second, by emphasizing the flexible use of resources to support new applications, strategic flexibility creates an environment in which the firm can better assimilate and use new information, which increases its potential absorptive capacity for developing explorative innovation (Matthyssens et al., 2005). Third, because strategic flexibility focuses on the rapid commitment of resources to new actions in response to change, it promotes a firm’s willingness to forgo existing investment in exchange for future development (Sanchez, 1995). Coupled with such flexible mechanisms, firms with great technological capability are more likely to search beyond the domain of neighborhood knowledge and embark on a broader level of exploration that transcends existing technological and organizational boundaries. Therefore, strategic flexibility makes the positive linkage between technological capability and exploration stronger.

**Hypothesis 3:** Strategic flexibility strengthens the positive effects of technological capability on exploration.

**METHOD**

**Sampling and data collection**

To test the hypotheses, we examine firms operating in high-technology sectors such as electronics, information technology, and telecommunication in China. China provides a rich setting to test our model because in this highly complex and dynamic transitional economy, the market environment changes rapidly, and new products, including both incremental and breakthrough innovations, are introduced into the market at an unprecedented pace. To survive the competition and maintain their competitive advantage, firms must not only exploit their existing capabilities but also develop new ones that are specific to the Chinese market (Li, Zhou, and Shao, 2009; Zhou, Yim, and Tse, 2005).

We first developed an English-language version of the questionnaire. Then, two independent translators translated it into Chinese and back translated it into English twice to ensure conceptual equivalence (Hoskisson et al., 2000). We discussed any conflicts with the translators until we reached an agreement. To ensure the content and face validity of the measures, we conducted five in-depth interviews with senior managers in which we asked
them to verify the relevance and completeness of the questionnaire items. On the basis of their responses, we revised a few questionnaire items to enhance their clarity. We then conducted a pilot study with 20 senior managers with titles such as chief executive officer (CEO), vice president, and general manager. We asked these respondents not only to answer all the questionnaire items but also to provide feedback about their design and wording. The results of this pilot survey revealed that all the items were well understood by the respondents. On the basis of the pilot test, we further refined the questionnaire and finalized the survey.

We selected a random sample of 500 firms from a list of high-technology companies located in Shanghai and its surrounding areas (Jiangsu and Zhejiang provinces) provided by a business research firm. To reduce common method bias, we interviewed one senior manager (e.g., CEO, vice president, general manager) and one middle manager (marketing, sales, R&D department manager) from each firm. We recruited trained interviewers to conduct onsite interviews, a critical means to generate valid information and high-quality data in emerging economies (Hoskisson et al., 2000; Li, Poppo, and Zhou, 2008). The interviewers presented the questionnaires to the two managers separately and collected the surveys after their completion. We successfully obtained responses from 195 firms (390 informants). We dropped three cases with excessive missing data and the remaining 192 cases contain full information of the variables under study. Therefore, the final sample consists of 192 firms (384 informants), for an effective response rate of 38.4 percent.

We obtained different information from different sources. Specifically, senior managers provided information about the strategic level, such as technological capability and strategic flexibility; middle managers provided data about the operational level, such as exploitation and exploration in new product development, as well as two control variables (i.e., market growth and technological turbulence). Information on firm age, size, prior performance, ownership, industry, and location came from archival data provided by the research firm, and information on industry-level performance was from archival data of the China National Bureau of Statistics. This procedure separates the sources of information and thereby effectively eliminates common method bias. To assess the informants’

quality, we asked them to indicate their knowledge level pertaining to the survey questions. The means of 6.19 and 5.87 (1 = little knowledge, 7 = a great deal of knowledge) for the senior and middle managers, respectively, indicate they are qualified respondents.

Of the 192 firms, most (75.9%) are small or medium in size with 500 or fewer employees, and 77.9 percent have annual sales revenues of more than US$3 million. In addition, 34.9 percent are Chinese firms, 31.8 percent international joint ventures, and 33.3 percent wholly foreign-owned firms. The largest industry segment is information technology (33.3%), followed by electronics (27.1%), computer equipment (18.8%), and telecommunications (11.5%). A comparison of participating and nonparticipating firms indicates no significant differences in terms of key firm characteristics, including age, number of employees, or sales (Wilks’ \(\Lambda = 0.957; F = 1.423; p = 0.658\)), so nonresponse bias is not a significant concern in our study.

Measures

In the Appendix, we provide the measurement items and their validity assessments. On the basis of Gatignon and Xuereb’s (1997) and Song and colleagues’ (2005) work, we develop a measure of technological capability that assesses a firm’s ability to use various technologies. To develop the measure of strategic flexibility, we use Sanchez’s (1995) theoretical work, which focuses on the flexible allocation and coordination of resources in response to changing environments. We adapt the measures of exploitation and exploration from Atuahene-Gima (2005); the items reflect the extent to which a firm uses existing or explores new knowledge and technologies in its product development.

To account for the effects of extraneous variables, we include firm age (age), firm size (size), firm ownership, firm prior performance (prior performance), technological turbulence (turb), market growth (grow), and industry-level performance

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1 To corroborate our perceptual measure, we collected additional archival data about R&D intensity, as reflected by the percentage of R&D expenses relative to sales. Many companies do not report this information, but we were able to obtain it from 73 (39.2%) of the 192 companies. The analysis shows that our measure of technological capability is related strongly to R&D intensity (\(b = 0.36, p < 0.01\)), in support of our measure.
(industry) as control variables. Firm age equals the number of years the firm has been in operation. We use the logarithm of the number of employees as an indicator of firm size. For firm ownership, we include two dummy variables: international joint ventures (IJV) and wholly foreign-owned (foreign), using domestic firms as the baseline (Li et al., 2008). We assess firm prior performance with an objective financial indicator, that is, the return on assets (ROA) of the year prior to our survey. We adapt items from Im and Workman (2004) to measure market growth and from Jaworski and Kohli (1993) to measure technological turbulence. Industry-level performance is captured by profitability, calculated as total industrial profits divided by total industrial outputs.

Construct validity. We refine the perceptual measures and assess their construct validity in accordance with Anderson and Gerbing’s (1988) recommendations. First, we run exploratory factor analyses for each multi-item scale (i.e., capability, strategic flexibility, exploitation and exploration, and environmental factors), which result in the theoretically expected factor solutions. The reliability analyses also show that these measures possess satisfactory reliability coefficients. Second, we estimate an overall, six-factor confirmatory measurement model. After dropping two items that possess either low factor loadings or high cross-loadings, the model achieves a satisfactory fit to the data (goodness-of-fit index [GFI] = 0.90, comparative fit index [CFI] = 0.91, incremental fit index [IFI] = 0.91; root mean square error of approximation [RMSEA] = 0.05). Furthermore, all factor loadings are highly significant (p < 0.001), the composite reliabilities of all constructs (0.818–0.946) exceed the 0.70 benchmark, and all average variances extracted (AVE) are greater than 0.50. These measures demonstrate adequate convergent validity and reliability (Fornell and Larcker, 1981).

We then assess the discriminant validity of the measures in two ways. First, we run chi-square difference tests for all the constructs in pairs to determine whether the restricted model (correlation fixed as 1) is significantly worse than the freely estimated model (correlation estimated freely). All the chi-square differences are highly significant (e.g., technological capability vs. strategic flexibility: Δχ²(1) = 197.44, p = 0.000), in support of discriminant validity (Anderson and Gerbing, 1988). Second, we calculate the shared variance between all possible pairs of constructs to determine if they are lower than the AVE for the individual constructs. The results show that for each construct, the AVE is much higher than the highest shared variance with the other constructs, in additional support of discriminant validity (see the Appendix) (Fornell and Larcker, 1981). Overall, these results show that our measures possess adequate reliability and validity.

In Table 1, we present the basic descriptive statistics and correlations of the measures. Consistent with the notion that exploration is more risky and involves more uncertain returns than exploitation, firms tend to engage in more exploitative (mean = 4.57) than explorative (mean = 3.77) activities. Technological capability relates positively to exploitation (r = 0.28, p < 0.01) and exploration (r = 0.39, p < 0.01), providing some initial evidence to Hypotheses 1 and 2. Strategic flexibility is positively associated with technological capability (r = 0.44, p < 0.01), suggesting that to understand the roles of technological capability and strategic flexibility in product innovation, the examination of their interaction is necessary.

ANALYSES AND RESULTS

To test our hypotheses, we employ a stepwise hierarchical regression approach to assess the explanatory power of each set of variables (Aiken and West, 1991). The models (M1–M7) are as follows:

Hypothesis 1: Exploitation =

Step 1 (M1): \[ \alpha_1 + \beta_1 \text{Age}_i + \beta_2 \text{Size}_i + \beta_3 \text{PriorPerformance}_i + \beta_4 \text{IJV}_i + \beta_5 \text{Foreign}_i + \beta_6 \text{Turb}_i + \beta_7 \text{Grow}_i + \beta_8 \text{Industry}_i + \beta_9 \text{SF}_i \]

Step 2 (M2): \[ + \beta_{10} \text{TC}_i + \beta_{11} \text{TC}_i^2 + \]

Step 3 (M3): \[ + \beta_{12} \text{TC}_i^3 + \epsilon_i. \]

Hypothesis 2: Exploration =

Step 1 (M4): \[ \alpha_1 + \beta_1 \text{Age}_i + \beta_2 \text{Size}_i + \beta_3 \text{PriorPerformance}_i + \beta_4 \text{IJV}_i + \beta_5 \text{Foreign}_i + \beta_6 \text{Turb}_i + \beta_7 \text{Grow}_i + \beta_8 \text{Industry}_i + \beta_9 \text{SF}_i \]

2 When discussing M1–M7, the abbreviations TC (technological capability) and SF (strategic flexibility) are used.
Table 1. Basic descriptive statistics of the constructs

<table>
<thead>
<tr>
<th>Construct</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exploitation</td>
<td>1.00</td>
<td>0.95</td>
</tr>
<tr>
<td>2. Exploration</td>
<td>0.29</td>
<td>1.11</td>
</tr>
<tr>
<td>3. Technological capability</td>
<td>0.28</td>
<td>1.03</td>
</tr>
<tr>
<td>4. Strategic flexibility</td>
<td>0.17</td>
<td>0.89</td>
</tr>
<tr>
<td>5. Firm age</td>
<td>−0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>6. Firm size</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>7. Firm prior performance</td>
<td>0.30</td>
<td>0.05</td>
</tr>
<tr>
<td>8. IJV</td>
<td>−0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>9. Foreign</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>10. Technological turbulence</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>11. Market growth</td>
<td>0.20</td>
<td>0.05</td>
</tr>
<tr>
<td>12. Industry performance</td>
<td>0.03</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Notes: N = 192. *p < 0.01, **p < 0.05.

Step 2(M5) : +β_{10}TC_i + β_{11}TC^2_i + ε_i.

Step 3(M6) : +β_{12}TC_i + ε_i.

Hypothesis 3: Exploration = (M7): α_i + β_1Age_i + β_2Size_i + β_3PriorPerformance_i + β_4IJV_i + β_5Foreign_i + β_6Turb_i + β_7Grow_i + β_8Industry_i + β_9SF_i + β_{10}TC_i + β_{11}TC^2_i + β_{12}TC_i × SF_i + β_{13}TC^2_i × SF_i + ε_i.

Step 3 (i.e., M3 and M6) includes a cubic term to examine whether the higher order polynomials may override the effects of TC-square. To deal with possible multicollinearity between the square, cubic, and interaction terms, we mean center each scale that constitutes an interaction term and create the interaction terms by multiplying the relevant mean-centered scales (Aiken and West, 1991). In these models, the largest variance inflation factor (a multicollinearity indicator) is associated with the cubic term, with a value of 4.06, well below the usual 10.0 benchmark. Thus, multicollinearity is not a major concern in our analysis. In Table 2, we present the results of the standardized regression estimates to allow for a direct comparison between coefficients with respect to their relative explanatory power of the dependent variable.

With Hypothesis 1, we consider the effect of technological capability on exploitation. As we show in Table 2, M2, both TC (b = 0.30, p < 0.01) and TC^2 (b = 0.19, p < 0.05) positively affect exploitation. That is, we find a J-curved effect between TC and exploitation, in support of Hypothesis 1.

Hypothesis 2 deals with the relationship between technological capability and exploration. As M5 shows, TC relates positively to exploration (b = 0.26, p < 0.01), whereas TC^2 negatively affects exploration (b = −0.17, p < 0.05). Therefore, TC has an inverted U-shaped relationship with exploitation, in support of Hypothesis 2. M3 and M6 further show that TC^3 is not significantly associated with either exploitation (b = 0.07, p > 0.10) or exploration (b = −0.07, p > 0.10). Therefore, adding higher level polynomials into the model does not make the estimation more effective.

To clarify these curvilinear relationships, we use the unstandardized parameter estimates to depict
Table 2. Standardized regression estimates (t-values)

<table>
<thead>
<tr>
<th>Control variables</th>
<th>Exploitation</th>
<th>Exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M1</td>
<td>M2</td>
</tr>
<tr>
<td>Firm age</td>
<td>−0.05</td>
<td>−0.03</td>
</tr>
<tr>
<td></td>
<td>(−0.66)</td>
<td>(−0.41)</td>
</tr>
<tr>
<td>Firm size</td>
<td>0.11</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(1.34)</td>
<td>(0.39)</td>
</tr>
<tr>
<td>Firm prior performance</td>
<td>0.31**</td>
<td>0.28**</td>
</tr>
<tr>
<td></td>
<td>(4.25)</td>
<td>(3.93)</td>
</tr>
<tr>
<td>IJV</td>
<td>−0.01</td>
<td>−0.02</td>
</tr>
<tr>
<td></td>
<td>(−0.09)</td>
<td>(−0.31)</td>
</tr>
<tr>
<td>Foreign</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(1.59)</td>
<td>(0.69)</td>
</tr>
<tr>
<td>Technological turbulence</td>
<td>−0.11</td>
<td>−0.10</td>
</tr>
<tr>
<td></td>
<td>(−1.31)</td>
<td>(−1.23)</td>
</tr>
<tr>
<td>Market growth</td>
<td>0.15†</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>(1.81)</td>
<td>(0.97)</td>
</tr>
<tr>
<td>Industry-level performance</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>Strategic flexibility (SF)</td>
<td>0.10</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>(1.28)</td>
<td>(0.48)</td>
</tr>
<tr>
<td>Direct effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology capability (TC)</td>
<td>0.30**</td>
<td>0.25**</td>
</tr>
<tr>
<td></td>
<td>(3.20)</td>
<td>(2.95)</td>
</tr>
<tr>
<td>TC²</td>
<td>0.19*</td>
<td>0.22*</td>
</tr>
<tr>
<td></td>
<td>(2.50)</td>
<td>(2.21)</td>
</tr>
<tr>
<td>TC³</td>
<td>0.07</td>
<td>−0.07</td>
</tr>
<tr>
<td></td>
<td>(0.49)</td>
<td></td>
</tr>
<tr>
<td>Interaction effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC × SF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC² × SF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.11**</td>
<td>0.17**</td>
</tr>
<tr>
<td>R² change</td>
<td>0.06**</td>
<td>0.00</td>
</tr>
<tr>
<td>Model F</td>
<td>3.67**</td>
<td>4.36**</td>
</tr>
<tr>
<td>DF</td>
<td>9,182</td>
<td>11,180</td>
</tr>
<tr>
<td>N (sample size)</td>
<td>192</td>
<td>192</td>
</tr>
</tbody>
</table>

** p < 0.01, * p < 0.05, † p < 0.10 (two-tailed).

the effects in Figure 1. Figure 1a clearly shows that technological capability has an increasingly positive effect on exploitation, but its impact on exploration declines after a certain point (see Figure 1b). These results fully support Hypotheses 1 and 2.

In Hypothesis 3, we assess the moderating role of strategic flexibility on the effects of technological capability. As M7 shows, the first-order interaction between SF and TC positively (b = 0.27, p < 0.01) affects exploration, whereas their second-order interaction negatively (b = −0.16, p < 0.05) relates to exploration, which indicates that strategic flexibility strengthens the positive effects of technological capability on exploration (Aiken and West, 1991). To gain more insight into the interaction effects of Hypothesis 3, we follow Aiken and West’s (1991) procedure to decompose the interactive terms. Specifically, we conduct simple slope tests and plot the relationships in Figure 1c. In the tests, we split the strategic flexibility variable into two groups—low (one standard deviation below the mean) and high (one standard deviation above the mean)—and estimate the effect of technological capability on exploration for both levels. As we show in Figure 1c, when
strategic flexibility is high, technological capability has a stronger positive effect on exploration; the first-order effect of technological capability on exploration is stronger when strategic flexibility is high ($b = 0.54, p < 0.01$) than when it is low ($b = 0.13, p < 0.10$). The optimal level of technological capability for exploration is moderate when strategic flexibility is low, whereas when strategic flexibility is high, the optimal level shifts to a higher point. These results suggest that strategic flexibility strengthens the positive effects of technological capability on exploration, in support of Hypothesis 3.

**Effects of control variables**

As Table 2 shows, strategic flexibility itself does not have a significant effect on either exploitation or exploration. To examine whether strategic flexibility moderates the capability–exploitation relationship, we run additional regression analysis and find that the interaction effect is not significant. Firm prior performance positively affects both exploitation and exploration, which suggests that better performing firms tend to have more exploitative and explorative product innovations. Firm ownership (IJV and foreign) relates positively to exploration, such that domestic firms lag behind IJVs and foreign companies in exploring new technologies and opportunities.

**Additional analysis**

A potential concern of our model is that the causality between capability and innovation may be reversed: exploitation and exploration may be antecedents of a firm’s technological capability. To address this concern, we employ a nonrecursive structural equation modeling approach to evaluate the potential bidirectional relations between capability and innovation. As Wong and Law suggest, ‘although the true effects may be longitudinal between some management constructs, it is not always possible for researchers to have data that match the exact time duration of the cross-lagged effects. In these cases, using the nonrecursive model as a proxy may be a viable alternative for studying reciprocal relations’ (Wong and Law, 1999: 71). Because the exact time lags between constructs are either unknown or impractical in terms of measurement, studies in strategy research often use cross-sectional data to examine causal relations (e.g., Poppo, Zhou, and Ryu, 2008).

We test a nonrecursive cross-sectional model that contains links from TC and TC$^2$ to exploitation and exploration, as well as from exploitation/exploration to TC/TC$^2$. The results show that TC ($b = 0.37, p = 0.001$) and TC$^2$ ($b = 0.25, p = 0.004$) positively affect exploitation, but exploitation does not affect TC ($b = -0.06, p = 0.425$) or TC$^2$ ($b = -0.08, p = 0.178$). Moreover, TC positively ($b = 0.33, p = 0.010$) and TC$^2$ negatively ($b = -0.21, p = 0.021$) influence exploration, but
exploration does not affect either TC ($b = -0.06$, $p = 0.742$) or TC$^2$ ($b = 0.10$, $p = 0.161$). These results support our original model specification; in line with the logics of absorptive capacity and organizational inertia, technological capability has a curvilinear and differential effect on exploitation and exploration.\(^3\)

**DISCUSSION**

Building on the absorptive capacity perspective and organizational inertia theory, we examine the effects of technological capability on exploitation and exploration. We find that technological capability has an increasingly positive effect on exploitative innovation but an inverted U-shaped relationship with explorative innovation. We further find that strategic flexibility enhances the positive relationship between technological capability and exploration. Our findings thereby contribute to existing literature in two major ways.

First, our findings provide a more nuanced understanding of the curvilinear effects of technological capability on exploitation and exploration. Previous literature highlights the role of technological capabilities for new product success in that a firm’s ability to acquire and apply various technologies is critical for product innovation (Anderson and Tushman, 1990; Gatignon and Xuereb, 1997; Lavie and Rosenkopf, 2006). Consistent with this logic, we find that technological capability enhances a firm’s use of its existing knowledge and expertise in product innovation. More interestingly, we find that technological capability fosters exploitation at an increasing speed (see Figure 1a). As a firm accumulates technological know-how, it likely becomes more efficient in evaluating, assimilating, and applying existing knowledge to product extensions and refinements. Organizational inertia can be expected to further reinforce such exploitative activities because they fit with existing routines and processes. In short, firms with strong technological capability are more likely to devote their resources to exploitation, which maximizes the potential of current competencies and strengthens their established positions.

Even more novel is our finding that technological capability has an inverted U-shaped relationship with exploration: a moderate level of technological capability relates to the highest degree of exploration, whereas a high level of technological capability actually inhibits firms’ exploration of new alternatives (see Figure 1b). Firms with strong technology capabilities may become so entrenched in existing technology trajectories that they might overlook emerging technologies from new territories and become unwilling or unable to migrate to new technology platforms. Organizational inertia may further discourage radical departures from the status quo, which would require a different set of rules and processes and provide only distant, uncertain returns. Therefore, rich experience and expertise in the existing technology base may decrease a firm’s intention to explore future opportunities that arise from a new dominant design.

These findings enrich extant literature by demonstrating the possible liabilities of capabilities: a strong technological capability may foster myopic learning and incremental innovations, but inhibit experimentation with new alternatives in emerging domains. These findings not only reconcile the conflicting views about the relationship between capability and innovation (e.g., Levinthal and March, 1993; Rosenkopf and Nerkar, 2001) but also add significantly to existing anecdotal evidence and case studies that indicate the failure of technology-leading firms in the face of rapid environmental change (Christensen, 1997, 2006).

Second, we advance extant literature by proposing and confirming empirically that strategic flexibility helps firms with superior technology sustain their exploration. Recent work calls for the identification of ‘dynamic capabilities’ that firms can use to adapt, integrate, and reconfigure their resources and competencies in response to changing environments (Eisenhardt and Martin, 2000), a field that suffers from a lack of empirical evidence (Lavie, 2006). In particular, researchers suggest that strategic flexibility promotes the flexible use and coordination of resources to support various technologies and products and thereby enables firms to move readily to new platforms and alleviate lock-in effects (Matthyssens et al., 2005). We propose that strategic flexibility as an organizing principle may not directly affect exploration; rather, it

\(^3\) We must caution that because our cross-sectional design lacks the precision to examine causality, this additional analysis does not rule out any reciprocal effects between capability and exploitation/exploration over a longer time period. Ideally, we would use data from two time periods, rather than the single time period currently available, to capture the inherent causal complexity in our model.
must work together with organizational capabilities to affect explorative activities. Consistent with our propositions, we find that strategic flexibility has no direct effect on exploration but instead enhances the positive effect of technological capability on exploration. That is, strategic flexibility makes the positive influence of technological capability stronger and shifts the optimal point of technological capability for exploration from a moderate to a higher level. Therefore, strategic flexibility appears to be one type of dynamic capability that enables firms to achieve the potential of their technological capabilities.

Our findings also provide some important managerial implications. Firms must be aware of the limitations of their existing capabilities in product innovations. For example, firms with a strong technological capability should understand that though their technological know-how greatly enhances their product extension and refinement, it may trap them in existing technological trajectories, lock them in with existing customers, and prevent them from exploring new options. Polaroid, once the market leader in instant film and cameras, missed the introduction of digital photography and was forced to declare bankruptcy in 2001. Similarly, despite Kodak’s success in becoming the market leader in digital camera sales in 2005 through its introduction of the ‘Kodak Easyshare’ camera, it continues to struggle to reinvent the company’s core business model, as its digital camera business turned out to be a huge profit disappointment (Hamm and Symonds, 2006). To overcome such challenges, technology-capable firms should develop strategic flexibility in their resource allocation and coordination. Such flexibility stimulates greater exploration of new technologies and markets, which may help firms escape the competence trap. To achieve a high level of flexibility, companies could design flexible organizational structures such as business units with self-organizing teams, develop flexible manufacturing processes with modular product design, and maintain an organizational culture that facilitates the rapid deployment of resources to deal with abrupt environmental changes (Christensen, 2006; Sanchez, 1999).

Our findings should be interpreted with some caution. First, our analysis of exploitation and exploration is limited to the domain of new product development. Further research should examine exploitation and exploration in other domains and investigate the role of technological capabilities in those contexts. Second, our measures of capability, exploitation, and exploration rely on managers’ judgments, though their perceptions may not coincide with reality. Objective measures, such as R&D intensity and number of patents, are useful for validating our propositions. Third, although we use absorptive capacity and organizational inertia theories to frame our hypotheses, we do not have their direct measures. Further research would benefit from assessing these variables directly and examining the processes through which technological capabilities affect innovation. Fourth, our study is cross-sectional, which limits the test of the causal inferences of capability and innovation. For example, during the process of exploiting their existing know-how, firms may enhance their technological capabilities. Related, how to achieve a balance between exploitation and exploration remains controversial (Gupta, Smith, and Shalley, 2006). Benner and Tushman (2003) suggest that the solution may require the simultaneous pursuit of exploitation and exploration through loosely coupled subunits, whereas Burgelman (2002) posits that cycling through exploitation and then exploitation (i.e., punctuated equilibrium) offers a more viable solution. Further research should tackle the dynamics of or coevolution between capabilities and innovations with a longitudinal study.

ACKNOWLEDGEMENTS

The authors thank the two anonymous reviewers and Associate Editor Rudi Bresser for their insightful and constructive comments on earlier versions. We also thank Kwaku Atuahene-Gima, Rajesh Chandy, David Deeds, and Mike Peng for their helpful comments. The study was supported by a research grant from the Research Grants Council, Hong Kong SAR Government (CERG HKU 7430/06H).

REFERENCES


Barney JB. 1997. Gaining and Sustaining Competitive Advantage. Addison-Wesley: Reading, MA.


Rosenkopf L, Nerkar A. 2001. Beyond local search: boundary-spanning, exploration, and impact in the...
K. Z. Zhou and F. Wu


Technological Capability and Product Innovation

APPENDIX: MEASUREMENT ITEMS AND VALIDITY ASSESSMENT

Overall model fit: \( \chi^2(443) = 948.22, \ p < 0.001; \ GFI = 0.90; \ CFI = 0.91; \ IFI = 0.91; \ RMSEA = 0.05 \)

Technological capability: Compared to your major competitors, how would you evaluate your firm’s capabilities in the following areas (1: much worse; 7: much better). CR = 0.888, AVE = 0.614, HSV = 0.270

1. Acquiring important technology information 0.799
2. Identifying new technology opportunities 0.781
3. Responding to technology changes 0.829
4. Mastering the state-of-art technologies 0.779
5. Developing a series of innovations constantly 0.689

Strategic flexibility: In responding to changes in the environment, your firm’s strategy emphasizes (1: strongly disagree; 7: strongly agree). CR = 0.898, AVE = 0.691, HSV = 0.268

1. The flexible allocation of marketing resources (including advertising, promotion and distribution resources) to market a diverse line of products 0.853
2. The flexible allocation of production resources to manufacture a broad range of product variations 0.938
3. The flexibility of product design (such as modular product design) to support a broad range of potential product applications 0.944
4. Redefining product strategies in terms of which products the firm intends to offer and which market segment it will target
5. Reconfiguring chains of resources the firm can use in developing, manufacturing, and delivering its intended products to targeted markets 0.668
6. Redeploying organizational resources effectively to support the firm’s intended product strategies 0.683

Exploitation: In the new product development processes, to what extent has your firm (1: very low; 7: very high). CR = 0.818, AVE = 0.531, HSV = 0.162

1. Upgraded current knowledge for familiar products
2. Invested in exploiting mature technologies that improve the productivity of current innovation operations 0.637
3. Enhanced abilities in searching for solutions to customer problems that are near to existing solutions 0.696
4. Upgraded skills in product development processes in which the firm already possesses rich experience 0.844
5. Strengthened the knowledge and skills to improve the efficiency of existing innovation activities 0.723

Exploration: In the new product development processes, to what extent has your firm (1: very low; 7: very high). CR = 0.946, AVE = 0.779, HSV = 0.179

1. Acquired manufacturing technologies and skills entirely new to the firm 0.841
2. Learned product development skills and processes entirely new to the industry 0.903
3. Acquired entirely new managerial and organizational skills that are important for innovation 0.888
4. Learned totally new skills in funding new technology and training R&D personnel 0.864
5. Strengthened innovation skills in areas where it has no prior experience 0.914

Technological turbulence (1: strongly agree; 7: strongly disagree). CR = 0.840, AVE = 0.579, HSV = 0.265

1. The technology in this industry is changing rapidly 0.826
2. Technological changes provide substantial opportunities in this industry 0.894
3. A large number of new product ideas have been made possible through technological breakthroughs in this industry 0.787
4. It is very difficult to forecast where the technology in this area will be in the next few years 0.565

Market growth (1: strongly agree; 7: strongly disagree). CR = 0.829, AVE = 0.621, HSV = 0.265

1. The growth rate of this industry in the past three years is very high 0.823
2. The market demand in this industry is growing rapidly 0.877
3. There are many potential customers in this industry to provide mass-marketing opportunity 0.647

* Item deleted from further analysis due to low factor loading or high cross loading.

Notes: SFL = standardized factor loading; CR = composite reliability; AVE = average variance extracted; HSV = highest shared variance with other constructs.