Absorptive capacity and the exploration–exploitation dilemma: Research on biopharmaceutical firms

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Abstract:

Firms' internal capacity to absorb external knowledge or technology play a critical role in open innovation implementation. Using data from 51 US bio-pharmaceutical firms between 1995 and 2006, we explore the extent to which firms' absorptive capacity influences exploration and exploitation. Results show that firm's cumulative experience is positively associated with the exploitation, and negatively with the exploration. Results also indicate that knowledge diversity has a significant positive effect on exploitation but not exploration.

Keywords : absorptive capacity; exploration; exploitation; innovation

Résumé :

La capacité interne de l'entreprise à absorber les connaissances externes joue un rôle crucial dans l'implantation de l'innovation ouverte. Ce papier a pour objet de voir comment la capacité d'absorption influence l'exploration et l'exploitation au travers d'une étude longitudinale de 51 entreprises biopharmaceutiques. Les résultats montrent que l'expérience cumulative est positivement liée à l'exploitation, et négativement liée à l'exploration. Les résultats montrent également que la diversité de connaissances a un effet positif sur l'exploitation. Cependant, les résultats de notre étude ne confirment cet effet sur l'exploration.

Mots-clés : capacité d'absorption; exploration; exploitation; innovation

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1. INTRODUCTION

In technology-rich firms, product innovation involves sourcing knowledge that are not held by any one firm (Xia, T. 2013). Firms have therefore shifted to an open innovation model, using a wide range of external actors and sources to combine both exploitation and exploration in order to create maximum value from their technological capabilities or other competencies (Chesbrough and Crowther, 2006; Lichtenthaler, 2008; van de Vrande et al., 2009). Since open innovation involves a variety of innovation activities, firms may have to develop relevant open innovation capacities in order to implement a specific open innovation mode (Ahn, Mortara and Minshall, 2013). In this paper, we explore the link between two key aspects of open innovation – absorptive capacity and two key innovation outcomes for the organization: exploration and exploitation.

Spithoven, Vanhaverbeke, and Roijakkers (2011) reviewed Cohen and Levinthal's (1990) "absorptive capacity" and suggest that capacities are vital in inflow open innovation modes. Empirical tests of how absorptive capacity relate to exploration and exploitation have associated absorptive capacity with exploration (Hoang and Rothaermel, 2010; Lavie and Rosenkopf, 2006; Rothaermel and Alexandre, 2009). There is limited understanding of how absorptive capacity relate to exploitation (Lavie, Stettner and Tushman, 2010). As Lavie et al. put it, "*most scholars associate absorptive capacity with exploration; yet applying external knowledge calls for exploitation*" (2010: 144). Additionally, in absorptive capacity literature the combination of exploration and exploitation is included in the conceptualization of absorptive capacity. For instance, Lane, Koka and Pathak (2006) and Lichtenthaler (2009) treat March's (1991) exploration and exploitation capabilities as separate absorptive capacity dimensions. However, they do not address the tensions that inherently are captured in the differences of their processes and routines, and how firms should manage these differences.

This study fills in this research gap by exploring the extent to which firms' internal capacity to absorb external knowledge or technology influences their abilities to develop new

knowledge and exploit its existing knowledge. We explore the influence of the two aspects of absorptive capacity –cumulative experience and knowledge diversity – on exploration and exploitation activities in human therapeutics biotechnology sector, where a key challenge is how to bridge the gap in both time and resources between discovery of a compound and earnings generated by sale of approved drugs (Mc Namara and Baden-Fuller, 2007). In particular, we propose a model where: (1) firm's cumulative experience is positively associated with exploitation, and negatively associated with exploration; and (2) firm's knowledge diversity is positively associated with exploration and exploitation. We test our ideas using data from 51 US bio-pharmaceutical firms between 1995 and 2006. Not only do we find that each of the constructs is important as predicted, but we also find that predictors of exploration- exploitation dilemma differ.

2. THEORY AND HYPOTHESES

To sustain their competitive advantage, firms must develop effective innovation routines to explore new opportunities and exploit "*old certainties*" (March, 1991: 71). Originally developed in the context of organizational learning, March (1991) defines exploration activities as including "*things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, inno*vation" (March, 1991: 71). In contrast, exploitation activities include "*such things as refinement, choice, production, efficiency, selection, implementation, execution*" (March, 1991: 71). Subsequently, Levinthal and March (1993: 105) defined exploration as "*the pursuit of new knowledge, of things that might come to be known*", and exploitation as "*the use and development of things already known*". The essence of exploration is experimentation with new ideas; it is associated with divergent thinking and flexibility. The essence of exploitation is the refinement of existing ideas; it is associated with convergent thinking and focus (March, 1991; Smith and Tushman, 2005). The relationship between exploration and exploitation is therefore considered as orthogonal in this study, as engagement with both types of innovation is simultaneously achievable because of the distinction between the sets of resources required to pursue these types of innovation (March, 1991; Gupta et al., 2006).

An organization's ability to explore and exploit is associated with its absorptive capacity (Lavie et al., 2010). Absorptive capacity theory (Cohen and Levinthal, 1990) explains how a firm's ability to recognize the value of external knowledge, assimilate it, and apply it is

critical to firm innovation. A firm's absorptive capacity is assumed to be a set of organizational capabilities by which firms acquire, assimilate, transform, and exploit outside knowledge to produce a dynamic capability (Zahra and George, 2002). Absorptive capacity enables firms to integrate external knowledge (Lichtenthaler and Lichtenthaler, 2009). In the open innovation paradigm, external as well as internal knowledge is a vital source for innovation, so a firm with strong absorptive capacity should make its boundary permeable to explore and assimilate external ideas in order to strengthen or compensate for their own low "inventive capacity" (Dyer, Kale and Singh, 2004).

A major tenet of absorptive capacity is that knowledge acquisition is cumulative and path dependent (Kogut and Zander, 1992). That is, a firm's ability to internalize external knowledge is a self-reinforcing function of its past knowledge and experience. Cohen and Levinthal's (1990) basic assumption is that prior related knowledge determines a firm's level of absorptive capacity (Lane et al., 2006; Tsai, 2001). Firms need some knowledge overlap with an external knowledge source to successfully absorb new knowledge, but a very strong overlap limits the possibilities of gaining new insights (Lord and Ranft, 2000; Mowery, Oxley and Silverman, 1996). Due to this path dependent property, various researchers have argued that firms with a greater cumulative and diversity of knowledge and experience are not only better able to internalize external knowledge, but this internalization subsequently increases a firm's memory and thus experience to assimilate and commercialize new knowledge in the next period (e.g. Bosch, Volberda and Boer, 1999; Lane et al. 2006; March and Stock 2003; Nerkar and Roberts 2004; Nicholls-Nixon and Woo 2003; Zahra and George 2002).

Thus, a firm's knowledge and experience play both the role of innovation and that of absorption (Cohen and Levinthal, 1989). Put differently, the drivers of absorptive capacity are highly correlated with the inputs from the innovation process as well as a firm's innovation ability (Escribano, Fosfuri and Tribo, 2009). Following this logic, we develop hypotheses about the influence cumulative and diversity of knowledge and experience on exploration and exploitation.

2.1. CUMULATIVE KNOWLEDGE AND EXPERIENCE

A key characteristic of absorptive capacity which has received little attention in literature so far is that it is cumulative and develops over time. This path-dependent and cumulative character is explicitly addressed by Cohen and Levinthal (1990) and is re-emphasized by Zahra and George (2002): "By having already developed some absorptive capacity in a

particular area, a firm may more readily accumulate what additional knowledge it needs in the subsequent periods in order to exploit any critical external knowledge that may become available" (Cohen and Levinthal, 1990: 136).

As a consequence of this path dependent property, a distinctive feature of this absorptive capacity concept is that a firm's experience positively influence its ability to innovate (Bosch et al. 1999; Lane et al. 2006; Zahra and George 2002). Namely, as a firm's cumulative knowledge and experience shape organizational memory so that future attempts trigger positive responses, thus reducing resistance to change and increasing commitment (Walsh and Ungson, 1991). As experience reflects a firm's successes and failures over time (Nelson and Winter, 1982), it can also significantly determine how firms acquire and assimilate new knowledge, as well as the locus of their future technological search (Zahra and George, 2002). Hence, as a firm accumulates increasing experience, it becomes increasingly open to new technological advances and thus increasing its ability to develop new products.

We propose that the cumulative knowledge experience will be positively associated with exploitation and negatively associated with exploration because exploitation requires retrieving knowledge that has already been created and internalized for use (Lyles and Schwenk, 1992) and creates reliability in experience through exploitation of existing knowledge (March, 1991). Firms accumulate experience as a result of path-dependent actions of learning (Dierickx and Cool, 1989) and will commonly build on current capabilities instead of exploring new areas. By exploiting current capabilities, there is a tendency to crowd out explorative activities which go beyond the beaten track (Schreyögg and Kliesch, 2007): "As organizations develop greater competence in a particular activity, they engage in that activity more, thus further increasing competence and the opportunity cost of exploration" (Levinthal and March, 1993: 106).

Due to the high costs associated with the product development process ($800 million / product) (DiMasi, Hansen and Grabowski, 2003), there are strong incentives to leverage a biotechnology firm's cumulative experience. By leveraging a biotechnology firm's cumulative experience, the biotechnology firm establish search routines that drive out a biotechnology firm's ability to assimilate new knowledge beyond existing technological boundaries. This follows Nerkar and Roberts' (2004) study of the biotechnology industry in which they argue biotechnology firms tend to not only leverage their technical experience, but in doing so favor a search within existing technological boundaries. Therefore:

Hypothesis 1: Cumulative knowledge and experience is positively associated with exploitation and negatively with exploitation.

2.2. KNOWLEDGE DIVERSITY

Knowledge diversity refers to "the scope of scientific and technological domains in which a firm has expertise" (Wu and Shanley, 2009: 476). The more diverse the firm's knowledge base, the more likely new knowledge is associated with existing knowledge, enhancing the absorption of new knowledge (Cohen and Levinthal, 1990; Zahra and George, 2002). As Cohen and Levinthal (1990) describe, diverse knowledge experience provides "…a more robust basis for learning because it increases the prospect that incoming information will relate to what is already known" (p.131). The association between new and existing knowledge are made easier, which increases the speed of learning (Fiske and Taylor, 2007).

We predict that a broad knowledge base will be especially important for exploration because they require recombination of more specialized and diverse knowledge than exploitation. With Knowledge diversity, a firm is not only able to assimilate a broader set of experience, but its assimilation increases a firm's "combinative abilities" to seek new resource linkages and configurations (Bosch et al. 1999; Cohen and Levinthal 1990; Zahra and George 2002). Such combinative abilities are important to the product development process because product innovations are driven by a process of novel resource and experience combinations (March and Stock 2003). A diverse knowledge base also allows the firm to build up "architectural competence" by integrating dispersed knowledge from the partners together into a coherent whole (Henderson and Cockburn, 1994).

Knowledge diversity also affects recognition in another way, as it influences the locus of search. Firms tend to search in areas that they already know, and where they had earlier (Zahra and George, 2002). This implies that firms which are experts in a very specialized knowledge field tend search in-depth for new knowledge which is more closely related to their existing knowledge base. Firms with board knowledge base, on the other hand, tend to search more broadly (Katila and Ahuja, 2002; Laursen and Salter, 2006). This implies that firms with higher knowledge diversity are inclined to search more broadly, hence have higher chance to identify new business opportunities.

A broad knowledge base provides Biotechnology firms with a stronger ability to innovate (Drew 2000; Hood 2003; Nerkar and Roberts 2004; Rader 2005). The drug development

process requires a successful biopharmaceutical firm to master a very wide range of technological disciplines, including molecular biology, physiology, biochemistry, analytic and medicinal chemistry, crystallography, pharmacology and so on (Rader 2005; Zhang, Baden-Fuller and Mangematin, 2007). As Peteraf (1993) points out, the employment of a Nobel Prize winning chemist is unlikely, in itself, to be a significant source of competitive advantage, and incumbents still need to learn or access a large range of complementary knowledge from new and smaller firms to maintain a high performance in drug development and commercialization (Zhang et al., 2007). Therefore:

Hypothesis 2: Knowledge diversity is positively associated with exploration and exploitation, and has a stronger association with exploration than with exploitation.

3. METHODES

3.1. SAMPLE AND DATA

To test our hypotheses, we collected data covering the years 1995-2006 for 51 U.S. public biotechnology firms fully dedicated to human therapeutics listed in BioScan. This segment of the biotechnology industry comprises new biotechnology firms engaged in the research, development, and commercialization of therapeutics that are placed inside the human body (in vivo) as opposed to in vitro therapeutics that are used outside the human body. The biotechnology industry offers an exciting context to analyze how organizations are able to manage two different but complementary issues: the ability to search for new knowledge – exploration-and the ability to use existing knowledge-exploitation. Data for measuring the variables are obtained from Bioscan, USPTO, and Thomson One Banker.

3.2. MEASURES

3.2.1. Exploration and exploitation

The two outcomes of interest in this study are exploration and exploitation. We used the public nature of the bio-pharmaceutical industry's R&D process to measure exploration and exploitation activities. Consistent with McNamara and Beden-Fuller (2007) measure, we classified the first two micro stages in the new product development process, namely patenting and preclinical trials, as exploration activities. We classified the remaining four micro stages as exploitation activities, namely the three phases of human clinical trials (phase

1, 2 and 3 trials) and the New Drug Application (NDA) regulatory approval process. In this industry, there is a clear validation process supported by regulated bodies for each of these six micro stages of the exploration–exploitation process.

3.2.2. Exploration and exploitation

Cumulative experience is measured using firm's age (Sorenson and Stuart 2000) and alliance experience (Rothaermel and Deeds, 2006). The age of firm can impact the extent to which a firm is receptive to new ideas (Hurley and Hult 1998; Lane et al. 2006; Sorensen and Stuart, 2000). In particular, Lane et al. (2006) argue that the age has been used to argue that older firms have higher absorptive capacity because they are likely to have accumulated knowledge and developed routines and processes that facilitate assimilation and innovation. Age is thus used to capture the routine aspects of a firm's cumulative learning. We measured a biotechnology firm's age by its age since founding. Alliance experience of a biotechnology firm is operationalized by its alliance years, which is the cumulative sum of the alliance duration for each of the firm's alliances (Rothaermel and Deeds, 2006). For example, if a firm has formed three alliances over the study period, with the first alliance 3 years old, the second 6 years old and the third 8 years old, the firm's total cumulative alliance experience would be 17 years. Through their prior collaborative experience, firms institutionalize learning mechanisms, legitimate the knowledge absorption process, and establish organizational routines that enable future learning to be more efficient and effective (Nelson and Winter, 1982; Zollo and Winter, 2002). For instance, studies of strategic alliances suggest that prior experience creates collaborative know-how, which enables a firm to transfer knowledge from a new alliance throughout the organization, integrate the new knowledge into its existing knowledge base, and apply it to create new products and processes (Bierly, Damapour and Santoro, 2009; Powell et al., 1996; Simonin, 1999).

Knowledge diversity is measured as a count of the number of technological sub-classes in USPTO classification in which the firm has been granted patents in the 5-year window (Birkinshaw, Nobel and Ridderstrale, 2002; Granstrand and Sjolander, 1990; Zhang et al, 2007). We took a 5-year window of prior patents for each firm and each year to assess the breadth of a firm's stock of knowledge. Using a 5-year time window is also consistent with prior research (e.g., Ahuja, 2000; Rothaermel

and Deeds, 2004; Zhang et al, 2007).

3.2.3. Control variables

To capture other factors that may impact on the relationships between absorptive capacity and exploration-exploitation dilemma, we control for a number of other possible effects including firm size, R&D expenditures and lagged dependent variables.

Firm Size. We controlled for firm size by using the natural log of the number of employees as a proxy because employees are also engaged in a firm's learning process (Graves and Langowitz 1993).

R&D expenditures. We used annual research and development expenditure in millions of dollars as a proxy for a firm's total R&D inputs to the innovation process (Katila and Ahuja, 2002).

Lagged dependent variables. We lagged the dependent variables by one-time period, and included it as a right-hand side variable. Inserting a lagged dependent variable provides for a conservative estimation of the other regressors, and allows us to control for a potential specification bias that can arise from unobserved heterogeneity (Jacobson 1990).

3.3. ESTIMATION PROCEDURE

The dependent variables - exploration and exploitation - are non-negative count measures. Verified by a statistical test for overdispersion (deviance / df = 7.0473 for exploration and deviance / df = 1.6374 for exploitation), the negative binomial estimation provides a significantly better fit for the data than the more restrictive Poisson model. Negative binomial regression accounts for an omitted variable bias, while simultaneously estimating heterogeneity (Hausman, Hall and Griliches, 1984). In theory, either fixed- or random-effects specification can be used to control for unobserved heterogeneity (Greene 2003). We applied a Hausman specification test (1978), and its result revealed that a random-effects estimation is appropriate.

4. FINDINGS

Table 1 depicts the descriptive statistics and bivariate correlation matrix. To assess the threat of collinearity, we estimated the variance inflation factors (VIFs), and found the average VIFs for all direct effect variables to be 1.14, with a maximum value of 2.54 when estimating firm

innovative performance. The VIFs were well below the recommended ceiling of 10 (Cohen et al. 2003).

Models 1 and 2 in Table 2 include only the control variables. The coefficients of firm size and positive and significant in Model 1, indicating that firms which are large are more likely to explore new knowledge. Large firms have in place the finances, people, and routines to implement exploratory innovation (Haveman, 1993). On the other hand, firm R&D spending has no significant effect on exploration and exploitation. Models 3 and 4 add the variables included in our hypotheses. Comparisons of these models with Models 1 and 2 indicate that adding the theoretical variables significantly improved the fit of the models for both exploration and exploitation, as X^2 change is significant for both models.

Hypothesis 1, which stated that cumulative knowledge and experience is positively associated with exploitation and negatively with exploitation, were supported by the data. We found that cumulative knowledge and experience indicators – firm age and alliance experience- negatively affects exploration (Model 3) and positively affect exploitation (Model 4).

Hypothesis 2 proposed that knowledge diversity is positively associated with exploration and exploitation, and has a stronger association with exploration than with exploitation. We found support for exploitation (Model 4)) but not for exploration (Model 3). This finding may suggest that a knowledge diversity in the context of biotechnology may be limited to human clinical trials and NDA and may not affect patenting and preclinical trials.

Table 1. Descriptive Statistics and Bivariate Correlation Matrix

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Exploration	11.36	20.52	1								
2. Exploitation	0.61	1.63	0.13	1							
3. Firm age	12.98	6.42	0.11	0.26	1						
4. Alliance experience	10.11	23.60	0.07	0.28	0.21	1					
5. Knowledge diversity	143.19	201.79	0.49	0.37	0.19	0.25	1				
6. Firm size (log)	2.18	0.58	0.55	0.36	0.29	0.28	0.64	1			
7. R&D expenditures (MM$)	75,84	197,38	0.47	0.44	0.30	0.24	0.59	0.67	1		
8. Lagged exploration	12.61	24.72	0.74	0.15	0.12	0.09	0.47	0.55	0.44	1	
9. Lagged exploitation	0.39	1.23	0.15	0.26	0.24	0.23	0.27	0.32	0.39	0.12	1

Table 2. Random-Effects Negative Binomial Regression analysis of exploration and exploitation

	Exploration		Exploitation		Exploration		Exploitation	
	Model 1		Model 2		Model 3		Model 4	
Variables	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Firm age					-0.177**	0.061	0.847***	0.200
Alliance experience					-0.465*	0.037	0.241*	0.104
Knowledge Diversity					0.029	0.070	0.355*	0.159
Firm size	0.647***	0.127	0.164	0.485	0.800***	0.126	0.741+	0.335
R&D expenditures	-0.030	0.051	0.006	0.003	-0.015	0.056	-0.133	0.143
Lagged exploration	0.311***	0.059	-0.011+	0.006	0.307***	0.057	-0.132	0.120
Lagged exploitation	0.024	0.031	0.162+	0.088	0.046	0.031	0.084	0.099
Constant	0.440	0.289	-1.399	0.936	0.104	0.285	-2.82***	0.755
−2 Log Likelihood	3249.0		984.3		3228.4		928.2	
Model improvement over the base model					20.6**		56,1***	

5. FINDINGS

This study adds to the small number of empirical studies that have focused on the relationship between absorptive capacity and exploration-exploitation dilemma. Indeed, prior research has identified internal R&D efforts as a prerequisite for learning and nurturing absorptive capacity. Nevertheless, although absorptive capacity enables exploration, it can result in "competency trap" or "dominant logic" behaviors that reduce a firm's ability to develop new knowledge, since the organization better assesses and comprehends new knowledge that is related to its knowledge base. The assumption that expansions in a firm's absorptive capacity will yield an increasing ability to explore is not necessarily valid. Therefore, this study examines the influence of the two aspects of absorptive capacity – the cumulative knowledge experience and the knowledge diversity – on exploration and exploitation activities. As such, our study addresses an existing deficiency in the extant literature by challenge the merits of a continued expansion of a firm's absorptive capacity for exploration versus exploitation (Lane et al., 2006; Lavie et al., 2010).

The results indicate that the predictors of exploration and exploitation differ. We found that firm's cumulative experience (proxied by firm's age and alliance experience) is positively associated with the exploitation (human clinical trials and NDA), and negatively with the exploration (patenting and preclinical trials). This finding is consistent with Cohen and Levinthal's (1991) argument that firms get 'locked out' of certain types of knowledge if they

do not acquire it early on and that they develop 'competency traps' whereby they are limited to the pursuit of a narrow set of opportunities suited to existing knowledge and experience. This is also consistent with Cognitive research which suggests that firms with greater cumulative experience are subject to systematic biases in their interpretation of new information (Daft and Weick 1984; Prahalad and Bettis 1986; Tripsas and Gavetti 2000). By leveraging a biotechnology firm's cumulative experience, the biotechnology firm is vulnerable to a confirmation bias. Such a bias promotes the development of search routines that drive out a biotechnology firm's ability to assimilate more distant biotechnological discoveries. This follows Rawlins' (2004) assessment of biotechnology firms where he argues biotechnology firms tend to "focus on improving approaches that have been clinically proven and financially successful, and have a disincentive to develop products for unmet medical needs" (p. 360).

In contrast to prior work emphasizing Knowledge diversity as the locus of exploration (Van Den Bosch and Van Wijk 2001; Van den Bosch et al. (1999), our findings indicate that knowledge diversity (proxied by the number of a firm's total number of distinct technological and/or research areas of specialization) has a significant positive effect on exploitation but not exploration. This finding points to the idea that that too rapid an expansion in a firm's knowledge may not provide enough time to develop the new knowledge. For instance, Vermeulen and Barkema (2002) argue that too rapid an expansion in a firm's knowledge base may not provide enough time to absorb the new knowledge. Furthermore, Lei and Hitt (1995) argue that expansion in knowledge through acquisitions may affect absorptive capacity negatively because of a firm's failure to develop its own absorptive capacity.

This study has important practice implications too. First, the finding that the cumulative experience influences a biotechnology firm's propensity to exploit its existing knowledge helps firms to avoid "competency trap" or "dominant logic" behaviors. Managers should be aware that the advantageous side of experience is attained by (unconsciously) suppressing alternatives, pluralistic ignorance and reduced flexibility. Second, the finding that a firm's diversity of knowledge has a positive influence on exploitation shows that a broad knowledge base may create more chances to increase the effectiveness of exploitation.

This study has several limitations. First, the study limits attention to a single industry, which may limit the potential for generalizing the results. Future work can include other high-tech industries. Second, and importantly we took a technologically biased view of exploration and exploitation, which we measured using the public nature of the bio-pharmaceutical industry's

R&D process. Obviously, this approach has the advantage of objectivity and robustness. But it does not capture many important dimensions of exploration and exploitation such as organizational diversity, diversification, variation and experience. Future work can define exploration–exploitation broadly in various domains. In addition, because the concept of absorptive capacity is multidimensional, the development of a unified or standardized measure of absorptive capacity remains a subject of much debate (Lane et al. 2006). This study's proposed measures of absorptive capacity are thereby not only subject to limitations surrounding this debate, but the proposed measures reflect one of the many dimensions of this concept. Future research should thereby develop measures that capture others aspects of this concept.

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