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Contents

Abstract:

In this paper we explore the relationship between two key aspects of open innovation in small firms – absorptive capacity and external relationships – and their effects on growth in the US and European biopharmaceutical sectors. Results from an international sample of 349 biopharmaceutical firms surveyed in the US, UK, France and Germany suggest that realized absorptive capacity plays an important role in determining firms' growth. In terms of the interaction between firms' absorptive capacity and external relationships, we find that engagement with exploratory relationships depends strongly on the continuity of R&D, while participation in exploitative relationships is more conditional on firms' realized absorptive capacity.

Keywords: Alliances, absorptive capacity, bio-technology, US, Europe

Introduction

Previous research has shown that open innovation is important for large high-tech companies developing new products (Chesborough, 2006; Cassiman and Veugelers, 2006). Previous studies have also emphasized, however, some of the constraints that small firms face, namely lacking slack resources and finding it difficult to identify and form relevant external partnerships (Hewitt-Dundas, 2006). This poses the question of how small firms can benefit from open innovation. Some scholars argue that open innovation may favour large rather than small firms, as small firms can only contribute to projects instead of controlling them due mainly to their lack of organisational infrastructures and resources. The behavioural advantages of small firms, such as internal flexibility and responsiveness, may however suggest that small firms can be equally good if not better than large firms at open innovation (Christensen et al., 2005; Stam and Elfring, 2008). Although research has been done on how small firms can successfully share ideas and access resources for innovation by adopting an open approach to innovation (Van de Vrande et al., 2009; Dahlander and Gann, 2010; Franzoni and Sauermann, 2013), less attention has been paid to the extent to which the ideas and resources acquired are actually absorbed and used within small firms and how they influence growth. In this paper we address these questions by exploring the links between two key aspects of open innovation - absorptive capacity (ACAP) and external relationships – and their impact on small business growth.

Our research links to the growing literature on complementarities between firms' internal characteristics and external resources in open innovation. For example, strong internal capabilities may enable a firm to more effectively target, absorb and deploy the external knowledge necessary to drive the innovation process (Fosfuri and Tribo, 2006; Escribano et al., 2009; Newey and Zahra, 2009). On the other hand, a firm's critical resources may span its boundaries and may be embedded in collaborative resources and routines (Dyer and Singh, 1998; Duysters and Lokshin, 2011).

Empirically, a number of studies have examined such complementarities between firms' in-house and extra-mural R&D, reflecting firms' choice between conducting in-house R&D, external R&D, or both (Veugelers and Cassiman, 1999; Cassiman and Veugelers, 2006; Fabrizio, 2009). Cassiman and Veugelers (2006) and Fabrizio (2009) also suggest that complementarities may arise between in-house and external R&D due to firms' improved scanning ability for external knowledge sources, the ability to exchange internally generated for externally sourced knowledge, enhanced absorptive capacity, and increased appropriation capacity. Similarly, Griffith et al. (2003) and Gomez and Vargas (2009) stress the dual role of firms' in-house R&D activity in directly generating knowledge and increasing firms' absorptive capacity. Other studies have, however, suggested the potential limits of such complementarities as the degree of managerial complexity involved increases (Laursen and Salter, 2006). In our study, evidence of a positive relationship between small firms' absorptive capacity and openness would provide further evidence for the importance of such complementarities.

We focus our research on small biopharmaceutical firms. This is an ideal setting, as the sector is generally dominated by small firms and previous studies have suggested that firms' external relationships play a central role in bio-technology (Deeds and Hill, 1996; Dowling and Helm, 2006; Gerwin 2004; Gilsing and Nooteboom, 2006) as firms seek external technology, expertise, and/or risk-sharing partners (Baum et al., 2000; Birkinshaw et al., 2007; Faems et al., 2010; Lasagni, 2012).

The paper makes two main contributions to the literature on open innovation. First, we develop and test a conceptual framework that links firms' internal ACAP capabilities and firms' involvement in exploratory and/or exploitative relationships. This allows us to examine the moderating effect between different dimensions of absorptive capacity and openness and link this to firm growth. Though both strategy and innovation scholars have extensively studied the complementarities between internal capability development and external linkages and their influences on performance,

little is known about the extent to which alliances and absorptive capacity may influence firm growth. Specifically, most studies on ACAP tend to examine the concept as a whole, few have looked at them distinctively. The theoretical distinction between potential and realized absorptive capacities helps us identify which components of internal capabilities matter more to the external linkages and growth trajectories of small firms. By examining and specifying these ACAP dimensions, we are also able to broaden the theoretical interpretation of the complementarities between both concepts. Second, while previous studies examined the motives, input and process of open innovation in large firms (Schmidt, 2007; Chiaroni et al., 2010; Fu, 2012), the effects of open innovation activities such as ACAP and types of openness have not yet been widely examined in the context of SMEs (Parida et al., 2012; Van de Vrande et al., 2009). Our study adds to our understanding of open innovation in SMEs both by modelling the interaction effects of different aspects of open innovation and their implications for SME growth.

The rest of the paper is organised as follows. Section 2 introduces the theoretical background and develops our conceptual framework, drawing on recent literature on absorptive capacity, open innovation and small business growth. This leads to hypotheses relating aspects of absorptive capacity to different aspects of openness and business growth. Section 3 describes our data and econometric approach, and Section 4 summarises the main empirical results. Section 5 concludes and discusses the main strategic and policy implications. The paper ends with a discussion of limitations and potential future research.

Theoretical background

The concept of open innovation was first introduced by Chesborough (2003) and suggests that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology. The main idea behind the concept is the deliberate import and export of knowledge by an organization to enhance

and accelerate its innovation. According to this view, firms should make use of innovative processes or inventions from other companies. Equally, internal inventions being used by a firm can be taken outside the firm (e.g. through partnerships, licensing or spin-off).

From a resource perspective, adopting an open approach to innovation allows small firms to overcome the liabilities of age and size by tapping into partners' resource networks and making extensive use of their manufacturing facilities, distribution channels and customer bases. In return, large incumbent firms can gain access to small start-up's technology and make use of their external knowledge and expertise (Powell and Brantley, 1992; Gassmann and Keupp, 2007). Moreover, firms that are seeking technologies or marketing resources from external partners, are more likely to assume that their competitors are doing the same. Failure to adopt an open strategy will put a firm at a severe disadvantage. From the perspective of organizational learning (Argyris, 1999), openness to external innovation enables small start-up companies to obtain or share external expertise across a variety of industries, disciplines and contexts. By contrast, learning is often captured in a rather reactive manner by large incumbent firms. Instead of making intensive internal investment in blue sky research for front-end innovation as suggested by the closed innovation model, the US Industry Research Institute's 2006 innovation study shows that 80 per cent of large companies across industries rely on external innovation for market growth, driven by an increased trend for academic technology development and spin-outs to form start-up companies (Streiffer, 2006; Kitson et al., 2009). It is known that innovation is inherently risky and therefore may increase the likelihood of both superior firm performance and bankruptcy. Open innovation helps small firms mitigate the uncertainty associated with innovation activities and allows risk and cost sharing (Chesborough, 2003; 2006). This may in turn maximize the profile of subsequent returns from their innovation and lead to different growth trajectories (Laursen and Salter, 2006).

ACAP and exploratory and exploitative relationships are key aspects of open innovation. It is widely acknowledged that implementing open innovation may extend across a wide range of firms' activities requiring firms to search, capture and control new knowledge through not only their internal capabilities but also external partnerships (Dyer and Singh, 1998; Duysters and Lokshin, 2011).

Absorptive Capacity

Cohen and Levinthal (1990) have offered the most widely-cited definition of absorptive capacity, viewing it as the firm's ability to value, assimilate, and apply new knowledge. They look at ACAP as a firm-level construct; an ability, which the firm develops over time by accumulating a relevant base of knowledge. Lane and Lubatkin (1998) on the other hand, shift the unit of analysis to the inter-firm level, and label it as a student-teacher paring or learning dyad. They show that the ability of a firm to learn from another firm is determined by the similarity of both firms rather than a single firm's knowledge base.

Nevertheless, these prior studies on ACAP have overlooked a firm's ability to value and assimilate new knowledge, placing limited focus on the internalisation and conversion of external knowledge (Fichman and Kemeter 1999; Koestler 1966; Smith and DeGregorio, 2002). Building upon this ground, Zahra and George (2002) offer a useful refinement on the notion of absorptive capacity extending the concept to include Kim's (1998) idea of transformation capability[1] , and developing the separate notions of 'potential absorptive capacity' (PACAP) and 'realized absorptive capacity' (RACAP). The conceptual distinction between PACAP and RACAP implies that firms can acquire and assimilate knowledge but might not have the capability to transform and exploit that knowledge for profit generation (Zahra and George, 2002).

[1] That is firms' capability to develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge.

Types of Openness

Koza and Lewin (1998) propose a framework which views strategic partnerships in the context of the adaptation choices of a firm. By employing March's framework of exploration–exploitation choices (1991), they argue that a firm's choice of the type of partnerships to enter can be distinguished by its motivation to either explore for new opportunities or exploit an existing opportunity. From this viewpoint, exploratory relationships are entered into with the motivation to discover something new and they emphasize the 'R' in the research and development process (Rothaermel and Deeds, 2004). Alternatively, exploitative relationships focus on the 'D' in the research and development process and are entered into with the goal of joining existing competencies across organisational boundaries in order to generate synergies, which are then shared across the partners (Rothaermel and Deeds, 2004). Strategic partnerships, in this view, are embedded in a firm's strategic portfolio, and co-evolve with the firm's strategy, the institutional, organisational and competitive environment, and with the management of the firm.

Conceptual framework and hypotheses

In this section we develop our conceptual framework linking absorptive capacity with firms' exploratory and exploitative relationships. This conceptual framework then leads to our empirical hypotheses. Our point of departure is Cohen and Levinthal's work (1989, 1990) on absorptive capacity – i.e. firm's ability to value, assimilate and apply new knowledge – and the distinction made by Koza and Lewin (1998) between exploratory and exploitative inter-firm relationships. Our focus is on the potential complementarities between firms' internal capabilities and their external relationships (e.g. Pittaway et al., 2004)[2]. Guellec and van Pottelsberghe (2004), for example, stress the role of business R&D in shaping firms' ability to absorb and capitalize on external knowledge, while Veugelers and

[2] For example, in terms of organisational learning (see Huber, 1991; Kim, 1998), industrial economics (see Cockburn and Henderson, 1998), and dynamic capabilities (see Mowery et al, 1996).

Cassiman (1999) suggest that companies undertaking in-house R&D benefit more from external knowledge sources than companies which have no in-house R&D activity.

Absorptive Capacity and Openness

Throughout the stages of the innovation process we are interested in the interaction between openness and firms' internal capabilities or ACAP (Figure 1). Since the original work of Cohen and Levinthal (1989; 1990) notions of ACAP have developed across a range of disciplines but all share the central idea that absorptive capacity is an organisational capability reflecting firms' receptivity to technological change (Kedia and Bhagat, 1988), and the ability of a firm to effectively use outside knowledge (Koza and Lewin, 1998; Fabrizio, 2009)[3]. Firms' decisions to engage in either exploratory or exploitative relationships will depend both on these internal capabilities (Winter, 1971; Levinthal and March, 1981) and their innovation objectives (Cyert and March, 1963; March, 1988)[4].

In many high-tech industries, exploratory relationships are widely observed (George et al., 2001), and are seen as playing an important role in the innovation process (Dowling and Helm, 2006; Gilsing and Nooteboom, 2006), a role supported by much empirical evidence (e.g. George et al., 2001; Koza and Lewin, 1998; Rothaermel and Deeds, 2004). One of the most widely cited motives for such collaboration is the acquisition of new technical skills or technological capabilities from partner firms (Shan, 1990; Hamel, 1991; Powell and Brantley, 1992). Exploratory relationships might therefore involve links to universities or other academic institutions

[3] A notable weakness of much of the literature on absorptive capacity is the implicit assumption that a firm has an equal capacity to learn from all other organisations regardless of their institutional or organisational form. Lane and Lubatkin (1998) overcome this to some extent by focusing attention on the learning dyad as the unit of analysis rather than the individual firm, and demonstrate that the ability of a firm to learn is greater where firms share some common characteristics.

[4] Alternative choice based perspectives (e.g. Radner and Rothschild (1975) and Hey (1982)) suggest that the balance between firms' investments in exploratory and exploitation alliances will reflect firms' evaluation of the relative returns. Others have argued, however, that this type of choice-based approach may be misleading due to the potential for new investment alternatives to emerge or for the probability distributions of outcomes to change or be dependent on the choices made by other firms.

(Streiffer, 2006; Kitson et al., 2009), small start-ups (Maurer and Ebers, 2006; Whitehead, 2003), or the licensing or buying-in of research services from contract research organisations (Miller, 2004).

The value of such exploratory relationships may, however, depend on firms' potential absorptive capacity. This is mainly because the rate and effectiveness with which knowledge acquired through a firm's exploratory relationships can be internalized is dependent on its ability to value and assimilate such knowledge (Koza and Lewin, 1998; Zahra and George, 2002; Xia and Roper, 2008). As depicted in Figure 1 this suggests our first hypothesis:

H1: PACAP will be positively associated with small firms' engagement with exploratory relationships.

Exploratory relationships may lead to the embodiment of new knowledge in firms' codified intellectual property and market offerings (Gilsing and Nooteboom, 2006; Rothaermel and Deeds, 2004)[5]. They may also stimulate organizational learning and increase firms' knowledge transformation capabilities, i.e. a firm's capability to develop and refine the routines that facilitate combining existing knowledge and the newly-acquired and assimilated knowledge (Zahra and George, 2000). This process of organizational learning is inevitably path dependent, however, as firms develop and extend their combinative capabilities through participation in boundary-spanning relationships (Eisenhardt and Martin, 2000; Parida et al., 2012). As depicted in Figure 1, this suggests:

H2: Engagement with exploratory relationships will positively influence small firms' RACAP.

RACAP represents firms' stock of codified knowledge – embodied in patents perhaps or prototype products – and based on combining existing

[5] Faems et al. (2006) define an explorative R&D alliance as an agreement between otherwise independent firms that pool their capabilities for the purpose of discovering new technological opportunities.

knowledge with newly-acquired and assimilated knowledge from external partners. Exploiting this knowledge might then be done by the firm alone or through exploitative relationships which enable the firm to link technological advance to potential market opportunities (March, 1991; Jansen et al., 2005; Van de Vrande et al., 2009). It is likely that firms with greater RACAP may have stronger incentives to engage in exploitative relationships than those with relatively weaker RACAP. As Figure 1 suggests:

H3: RACAP will be positively associated with small firms' engagement with exploitative relationship.

Absorptive Capacity, Openness and Firm Growth

The final link in the innovation process is that between RACAP and business growth (i.e. Rothaermel and Thursby, 2005; Van den Bosch et al., 1999). Here, firms' exploitative relationships may provide a co-ordinating framework within which partners with complementary technological and market resources are able to achieve the greatest pay-back (Stuart, 2000; Teng, 2007). Such performance gain is greater than the sum of those obtained from the individual endowments of each partner (Dyer and Singh, 1998), as exploitative relationships are made up of socially complex routines and mechanisms, resources when combined in this way become more valuable, rare, and difficult to imitate than they had been before they were combined (Dyer and Singh, 1998). Realized absorptive capacity may also improve a firm's growth by "exploiting existing internal and external firm-specific competencies to address changing environments" (Teece et al., 1997, p.510). In fact, Rothaermel and Thursby (2005) suggest that absorptive capacity itself is a set of firm-level capabilities that is expected to be heterogeneously distributed among firms and thus, should lead to variance in their growth. For small high-tech start-up firms, exploitative relationships are formed to commercialize their existing technologies, and ensure their current viability by making them become more efficient in using what they already know (O'Reilly and Tushman, 2007). Equally, their

existing knowledge stock is of particular useful in the exploitation of subsequent technologies (Dosi, 1982; Fagiolo and Dosi, 2003; Rothaermel, 2001). Thus, we anticipate as in Figure 1 that:

H 4a: RACAP will have a positive impact on small firms' growth.

H 4b: Engagement with exploitative relationships will have a positive impact on small firms' growth.

Data and Methods

Sample and data collection

The setting for our study is the biopharmaceutical sector. This sector is of particular interest as past studies have emphasized the importance of inter-firm collaboration in innovation, and the particularly costly, protracted and risky nature of biopharmaceutical innovation activity (Pisano, 1990; Ernst & Young, 2006). These peculiar characters of the innovation process suggest that effective use of external innovation and/or marketing resources through exploration and/or exploitation relationships can potentially help small companies accelerate new product development speed and reduce time to market. The objective of our data collection was to obtain information on the absorptive capacity, open innovation activities and growth of representative groups of biopharmaceutical firms from the US and three major European economies (i.e. France, Germany and the UK)[6]. Separate exercises were undertaken to define target populations for the company survey in Europe and the US. In the US, we obtained information on firms in the broader biotechnology sector from the Bioscan industry directory (see also Deeds and Hill, 1996; Rothaermel and Deeds, 2004; Zollo et al., 2002). For the European economies the target group was based on data provided by Biotechnology-Europe.com which is the most

[6] Together these economies account for around 50 percent of the entire population of biotechnology firms in Europe, with a distribution of 17 per cent in the UK, 11 per cent in France, and 22 per cent in Germany (Ernst & Young, 2006).

comprehensive list of firms in the European biotechnology industry[7]. Once comprehensive lists of biotechnology firms had been identified we reviewed each firm's product profile and verified their inclusion in our final list of biopharmaceutical firms. We also excluded service firms (e.g. consultancies, technology transfer organisations, incubator centres, investors in biotechnology companies) at this point as well as organizations that were active in the bio-pharmaceutical sector but which were not formal legal entities. This resulted in a US target group of 999 biopharmaceutical firms with 1099 in Europe (343 English firms, 247 French companies and 509 Germany companies).

Once the target groups of biopharmaceutical firms had been identified each company was approached by telephone to confirm contact details, explain the purpose of this research, and encourage their participation in the study. Survey design was informed by inductive interviews with six R&D managers from five English biopharmaceutical firms. These interviews which lasted 40-90 minutes each helped to clarify key concepts and verify the transparency of metrics for absorptive capacity, open innovation, etc. Further verification of the questionnaire design was provided by a pilot postal survey covering 75 Irish biopharmaceutical companies to pre-test the initial design for the English language questionnaire. Following some minor changes to the English language questionnaire, French and German versions were developed. In each case questionnaires were cross-translated by two different translators and any differences in meaning resolved. The main survey was administered to the final target list of 2,173 US and European biopharmaceutical firms between June and October 2006. An initial mail shot including freepost response envelope, was followed-up after two weeks by telephone and a further mailing. Finally, we obtained useful responses from 349 biopharmaceutical firms, an overall response rate of 16.1 per cent. Individual country response rates were: US, 14.4 per cent, Europe 17.5 per cent (UK 23.9 per cent, France 14.2

[7] In particular, the number of companies contained in this directory is close to the number of firms reported in the 2006 benchmark study by Ernst & Young.

per cent, Germany 14.0 per cent and Ireland 22.7 per cent). The average respondent firm had 47 employees, with US firms being larger (average 65 employees) than those in the EU countries (35 employees) (Table 1).

Measures

In the survey we measure *PACAP* conventionally (Kim, 1997; Zahra, 1996; Schmidt, 2005) using workforce R&D engagement, related prior knowledge and employee skills. Workforce R&D engagement is a continuous variable reflecting the proportion of a firms' workforce engaged in R&D activity. Our main focus here is the role of workforce R&D engagement in shaping firms' ability to import external knowledge (Stock et al., 2001). Employee skills are a continuous variable capturing the percentage of employees with an undergraduate degree in any subject. Well educated employees not only enhance the levels of assimilation and application of external knowledge (Freel, 2005) but also facilitate knowledge sharing within a firm (Schmidt, 2005). Related prior knowledge is a dummy variable indicating the continuity of firms' R&D engagement[8]. It is assumed that a firm which is continuously involved in R&D should possess more previously accumulated knowledge related to a specific field than other firms performing R&D occasionally (Table 1)[9]. Average workforce R&D engagement (i.e. the proportion of the workforce engaged in R&D) was around 42-45 per cent in Europe and the US with around 86-88 per cent of firms engaging in R&D on a continuous basis. Around 67-71 per cent of firms' employees had a degree or its equivalent. Variable correlations are given in Table 2.

[8] In the survey firms were asked 'How would you describe your investment in R&D over the last three years?' and asked to indicate either 'continuous', 'occasional' or 'infrequent'. The first option only was treated as the firm having had continuous R&D.

[9] Correlations between the three PACAP variables were relatively weak however suggesting that each variable reflects a different dimension of firms' knowledge absorption capability. Correlations were: workforce R&D engagement and employee skills, 0.26; workforce R&D engagement and continuous R&D, 0.27; continuous R&D and employee skills 0.03 (Annex 1).

To represent *RACAP*, we again use a conventional measure – firms' stock of patents[10] - a measure which suggests a marked contrast between US and EU firms. The average number of patents held by US firms (50.1) is more than twice that held by the European firms (20.2). For a firm to get a patent approved, it has to demonstrate a certain degree of newness that reflects a change in the firm's basic knowledge structure (George et al, 2001). This is mainly achieved by knowledge exploitation in that systematic exploitation routines guarantee the persistent creation of new knowledge (Spender, 1996). The number of patents, therefore, denotes a certain level of capability to exploit external new knowledge, and reflects firms' ability to incorporate new external knowledge into their operations (Zahra and George, 2002).

Openness is measured by the number of exploratory and exploitative relationships in which firms engage (Rothaemel and Deeds, 2004; Xia and Roper 2008). Exploratory relationships are those which focus on upstream activities in a firm's value chain, i.e. basic research, drug discovery, preclinical development[11]. Exploitative relationships are marketing-based linkages that focus on downstream activities, i.e. clinical trials, FDA regulatory process, marketing and sales[12]. On average, respondent firms have an average of 2.8 exploratory relationships, a higher average among US firms (3.0) than among firms in the EU (2.6) (Table 1). Similar results are also found in terms of exploitative relationships, with the average number higher in the US (2.2) than in Europe (2.0). US firms in the sample are also marginally older, larger and more likely to be independent than

[10] Due to data limitations we can only use firms' current stock of patents as a measure of firms' realized absorptive capacity. Ideally, we might have used depreciated patent stocks (Park and Park, 2006) or citation weighted patents (Jaffe et al., 2002), however, we have no information on individual patents and so can neither apply depreciation rates or citation weights.

[11]The specific question asked in the survey to identify the number of exploratory relationships was: 'Please indicate the total number of alliances or partnerships focusing on basic research, drug discovery and development you have currently?'

[12] In the survey exploitative relationships were identified with the question: 'Now we would like to ask about your commercialisation activities, e.g. clinical trials, FDA regulatory process, marketing and sales, etc. Please specify if you have any alliances or partnerships to help with these activities…?. A subsequent question asked respondents to specify the number of such alliances or partnerships.

those in the European sample. They are also more likely to be engaged in the early stages of the discovery process but less likely than the EU firms to be engaged in sales or marketing activity (Table 1).

Firm growth is measured by sales growth over a three year period - a key indicator widely used by both practitioners and academics in the evaluation of new venture performance (Stuart, 2000). Alternative approaches to measuring performance, such as market share and market share growth were also considered, but posed significant problems due to difficulties in defining of market and industry boundaries (Grant, 1991). To capture other factors that may impact on the relationships between openness, ACAP and growth we control for a number of other possible effects including firm size, age, ownership status, primary markets, strategic focus and location (EU/US). Firm size and age are the most commonly used control variables in studies focusing on the biotechnology industry (Quintana-Garcia and Benavides-Velasco, 2004). A biotech firm's success might be a positive function of the age (experience) and size as a measure of the strength of the company (Quintana-Garcia and Benavides-Velasco, 2004). It is also important to note that a biopharmaceutical firm's ownership, main markets and strategic focus (i.e. Deeds and Hill, 1996; George et al., 2001), are seen as important background factors to its external relationships, resource base, capabilities and sales growth. Finally, as there may be significant institutional or environmental effects we use location as a dummy variable to control for EU-US differences (0=US, 1=EU) (Rothaermel and Deeds, 2006).

Analytical approach

In terms of estimation, the dependent variable for Hypothesis 1– the number of exploratory relationships in which firms are engaged - is a count variable which displays marked signs of over-dispersion relative to the Poisson distribution (Table 1). This suggests the potential value of the negative binomial model. However, as around 36 per cent of firms in the sample have no exploratory relationships there is also the possibility that a

zero inflated negative binomial model may be relevant. To test this possibility we perform a Vuong (1989) test to compare the zero inflated negative binominal model with the standard negative binominal model[13]. The results point to a significant difference between the two models suggesting the appropriateness of the zero inflated negative binomial (ZINB) formulation. Essentially similar considerations are relevant to Hypothesis 3 relating to firms' engagement with exploitative relationships where the Vuong test also suggests the ZINB estimator is appropriate[14].

In terms of Hypothesis 2 the dependent variable, our indicator of RACAP, is the number of patents, a count variable which takes only non-negative integer values including zero. Again the patent distribution is skewed to the right, and has marked over-dispersion relative to the Poisson distribution, again suggesting the possibility of using the negative binominal approach (e.g., Graves and Langowitz, 1993; Henderson and Cockburn, 1996). A Vuong test again suggests the relevance of the ZINB estimator[15]. In the final stage of the innovation process (i.e. Hypothesis 4) we consider sales growth as an indicator of firms' market performance and use a truncated regression approach reflecting our omission of a small number of extreme values.

Robustness check

We acknowledge that there are potential endogeneities between variables in our two sets of hypothesized relationships - continuity of R&D and number of exploratory relationships (H1), number of patents and exploitative relationships (H3). Firms engaging in exploratory relationships are more likely to be continuously involved in R&D activities. Similarly, a firms' patent record may also have an important influence on their attractiveness as partners. To control for these potential endogeneity

[13] In a Vuong test of the zero inflated negative binomial vs. standard negative binomial: z = 19.2, Pr>z = 0.0000.
[14]Vuong test of zero-inflated negative binominal vs. standard negative binomial: z = 1.98, Pr>z = 0.024
[15]Vuong test of zero-inflated negative binominal vs. standard negative binomial: z = 6.9, Pr>z = 0.0000

biases, instrumental-variable methods were used for the continuity of R&D and patent variables. We first examined the validity of the instruments using the Sargan over-identification test. If the instruments proved to be valid, we then examined the extent of the potential endogeneity problem using a Hausman test. Our instruments included external funding and firms' competitiveness in commercial partnerships. External funding is a dummy variable indicating whether or not firms have ever received any external funding. R&D continuity is influenced by this indicator because for small start-up firms, sustaining their R&D activities is to a large extent determined by the receipt of external funding (David et al., 2000). We also utilized firms' own assessment of their competitiveness in partnerships focusing on new product commercialization, since they are more likely to capitalize on the areas where their competitive advantage lies. The estimated results of the Sargan test suggest that these instruments are valid and the results of Hausman test for endogeneity indicate that there is no significant endogeneity between continuity of R&D, number of patents and number of exploratory relationships[16].

Our survey firms are small companies in an emerging sector and no consistent secondary data source exists covering biopharmaceutical firms in the US and Europe. This limits our ability to externally verify individual responses. However, we attempted to control for common method bias by guaranteeing response anonymity, counterbalancing the question order and structuring the questionnaire to separate the measurement of predictor and criterion variables (Podsakoff et al., 2003). In addition, we conduct a Harman's single-factor test of all variables in this study. Exploratory factor analysis identifies seven factors with eigenvalues greater than one with the first factor accounting for only 12 per cent of the total variance.

[16] The estimated probability values of the Sargon test of the null hypothesis that the excluded instruments are valid for continuity of R&D and patent record are respectively, 0.662 and 0.763. The estimated probability values of Hausman test of the null hypothesis of exogeneity for R&D and patent record are respectively, 0.910 and 0.276. In addition, we re-estimated Model 2 including PACAP as a control variable. The results suggest very similar patterns to those reported in Table 3 with no difference in the significance and direction of the coefficient of each independent variable.

Independent and dependent variables of each of our equations clearly loaded on different factors.

Results

The initial stage of the innovation process (Figure 1) is reflected here in firms' knowledge seeking through exploratory relationships. Zero inflated negative binomial estimates of equation (1) linking firms' engagement with exploratory relationships and PACAP are reported in Table 3. In terms of the three PACAP indicators we find, first, a positive but insignificant relationship between workforce R&D engagement and the number of exploratory relationships in which firms are engaged. More significant effects are identified for the other PACAP indicators – firms' engagement in continuous R&D and employee skills.

In addition to the main variables of interest, other factors also prove important in contributing to firms' engagement with exploratory relationships (Table 3). First, firm age is negatively associated with firms' engagement with exploratory relationships, reflecting perhaps increasing internal capabilities as firms become mature. Second, we find an inverted U-shape relationship between firm size (employment) and the number of exploratory relationships, with its maximum at around 220 employees. This result reflects results from the innovation literature of an inverted U shape relationship between firm size and innovation activity. One possible explanation for this inverted 'U' shape relationship suggested by Schmidt (2005) is that as a firm grows and approaches the technological frontier it may have less incentive to seek external knowledge. Finally, firms' market orientation has no apparent impact on exploratory relationships but this is linked to firms' strategic focus on the initial stages of the discovery process, i.e. R&D and pre-clinical development (Table 3).

Our conceptual framework then suggests that firms' engagement with exploratory relationships together with PACAP might contribute to RACAP as suggested in Hypothesis 2. Table 3 (Model 2) reports our ZINB model of RACAP. We find some evidence that engagement with exploratory

relationships has a significant and positive impact on RACAP (measured here by the number of patents) but little evidence that the extent of firms' exploratory relationships is an important determinant of RACAP. Here, however, it is appropriate to acknowledge that issues of the direction of causality are potentially important as firms' patent record may also be an important influence on their attractiveness as partners.

Once useful knowledge has been acquired and assimilated internally, firms will then exploit and commercialize this knowledge through exploitative relationships (Figure 1). Table 3 presents the results from the zero-inflated negative binominal estimation (ZINB) of the influence of RACAP on exploitative relationships[17] (Model 3, Table 3). In terms of our parameters of interest, we find that RACAP does have a significant impact on firms' engagement with exploitative relationships. Other factors which also prove important in shaping firms' engagement with exploitative relationships are identified. First, we find an inverted U-Shape relationship between firm size and number of exploitative relationships (Table 3)[18]. This result provides partial support for earlier research which reported firm size as being significant in predicting a firm's number of exploitative relationships (Rothaermel and Deeds, 2004). Secondly, in terms of firms' strategic focus, the most important influence on firms' engagement with exploitative relationships, perhaps unsurprisingly, proves to be a strategic focus on the commercialisation stage of the innovation process, in particular marketing and sales activities. Equally, a strategic focus on the basic R&D and pre-clinical development proves to be the main barrier of firms' participation in exploitative relationships.

[17] However, considering the fact that more than 58 per cent of our respondent firms do not have any exploitative alliances, it is worthwhile to study those firms which are currently engaging in the exploitative alliances. We test the proposed relationship between RACAP and exploitative alliances on those firms with existing exploitative alliances, using the negative binominal regression model (NBREG). The results obtained are fully consistent with the previous results from our zero-inflated negative binominal estimation of the same relationship for the whole sample (in Table 3).

[18] Comparing the marginal values suggests that the number of exploitative alliances peaks around 170 employees.

Finally, our conceptual framework suggests that both RACAP and engagement with exploitative relationships will play important roles in influencing firms' growth (Figure 1). Truncated regression estimates of Hypothesis 4 are given for all of our respondent firms (Table 4). In terms of RACAP variables, we find a significant and positive relationship between number of patents and sales growth[19], suggesting that our profile of firms are under-exploiting their existing knowledge base[20].This is particularly true in an industry like biopharmaceuticals, where radically new technologies typically involve discontinuities, and only a proportion of firms' existing knowledge is likely to be useful in the exploitation of subsequent technologies (Fagiolo and Dosi, 2003; Rothaermel, 2001). However, we fail to find evidence of a significantly positive relationship between exploitative relationships and firm growth, instead the relationship moves in the opposite direction. The suggestion is that the main growth effect of openness is indirect, with exploratory relationships positively influencing realised ACAP (i.e. patents) and this, in turn, influencing growth[21].

Discussion

Our aim in this paper was to explore the relationships between openness, ACAP and growth in the innovation process of small firms. Our results emphasize the potential value of combining internal and external knowledge in innovation in very much the manner envisaged in the open innovation literature. However, it appears that although firms extensively develop external relationships to access complementary resources, this does not necessarily contribute to their growth. Rather, the growth benefits of external knowledge are conditional on firms' internal resources with the primary growth effect of openness operating through its effect on firms' realized absorptive capacity.

[19] Comparing the marginal values suggests that sales growth peaks around 80 patents.

[20] In other un-reported experiments we also found evidence of a significant inverted U-shape relationship between number of patents and sales growth. However, bearing in mind that the majority (around 82.5 per cent) of our respondent firms have less than 30 patents, the effect of number of patents on firms' sales growth is considered to be significantly positive within the scope of this study.

[21] The insignificant coefficient on the exploratory alliance variable in Table 4 also suggests that there is no significant direct link between exploratory alliances and business growth.

Our results provide broadly-based support for the argument that the R&D aspect of potential absorptive capacity plays an important role in shaping firms' exploratory relationships (Grimp and Sofka, 2009; Fabrizio, 2009; Spithoven et al., 2011). However, it is the continuity rather than intensity of R&D which matters most. In other words, R&D investment itself is not enough to make exploratory relationships work. Rather, firms need a certain level of continuity of R&D to internalize the external knowledge that has been acquired, or at least to facilitate the external learning process. These results reflect the findings of previous studies which have suggested the importance of firm's internal R&D in shaping their ability to import, comprehend, and assimilate external knowledge (Kim 1997; Kodama 1995; Vanhaverbeke et al., 2008; Huizingh, 2011).

From our survey based data it is not possible to identify the precise causal mechanism by which R&D continuity influences firms' engagement in exploratory relationships. However, it seems reasonable to argue that firms engaged in continuous R&D are likely to have stronger innovative capabilities and more products in development than those involved in R&D occasionally or infrequently (Acs and Audretsch, 1989; Scherer, 1980). This may provide incentives for potential partners who might gain more from forming exploratory partnerships with firms which have an established pipeline of outputs (e.g. patents, products in development) from their R&D activities (Coombs and Deeds, 2000). In addition, exploratory relationships, as we have defined them previously, are formed with the explicit purpose of learning (Koza and Lewin, 1998). Both partners must see some potential for learning from each other (Sen and Egelhoff, 2000; Robertson et al., 2012), as evident by the strong intention of skill acquisition of such collaboration shown in our results. Hence, firms which engage in R&D only occasionally or infrequently, with relatively weak innovative capabilities, may find fewer willing partners (Sen and Egelhoff, 2000). In our analysis the skills based indicators of PACAP have a significant but negative effect on firms' exploratory relationships – providing evidence for a substitute

relationship between firms' internal capabilities and exploratory relationships (Leiponen, 2005; Fabrizio, 2009; Robertson et al., 2012).

In terms of the impact of exploratory relationships on RACAP we find that engagement with exploratory relationships contributes positively to the development of firms' RACAP. This result provides empirical support for earlier studies which find that R&D based partnerships expand a firm's absorptive capacity or innovativeness as measured by the number of patents (Scott, 2002; Sampson, 2007)[22]. For most biopharmaceutical firms, however, exploratory relationships not only offer access to external new knowledge, but also provide opportunities for these firms to discover new insights, or recognise new opportunities which fit existing practice. This in turn allows the firms to develop and refine the routines that facilitate combining existing knowledge and newly-acquired external knowledge, i.e. to develop their own absorptive capacity (Powell et al., 1996; Huizingh, 2011; Hoang and Rothaermel, 2010).

Our evidence of a positive link between RACAP and firms' exploitative relationships reflects the results of previous research which suggested patents as a significant positive predictor of exploitative relationships (Rothaermel and Deeds, 2004; Spithoven et al., 2011). A well-developed knowledge-exploitation capability facilitates the exploitation of public research results (Wolter, 2003), and increases the level of networking among private and public investors, universities and specialist firms (Owen-Smith et al., 2002), thereby fostering the growth of market-based (exploitative) relationships.

Our evidence on the impact of RACAP on firms' growth suggests RACAP (measured by number of patents) plays an important role in shaping biopharmaceutical firms' growth. This empirically corroborates the

[22] While this empirical result is clear it is possible that what we are observing here is the impact of exploratory relationships on joint patents which is being reflected in firms' patent counts. Arguably such an impact still represents an increase in RACAP but ideally we might wish to remove any joint patents from the RACAP count in order to identify a clearer effect. This is not possible from our survey data, but we are grateful to an anonymous referee for suggesting this clarification.

argument of superior knowledge exploitation capability as one of the important factors which drive superior innovation and performance (i.e. Van den Bosch et al., 1999; Escribano et al., 2009; Newey and Zahra, 2009), and reflects the results of previous studies which suggest patenting activities as an important factor affecting firms' innovation performance and subsequent growth (McMillan and Mauri, 2003; Atun et al., 2006; Niosi, 2003; Fabrizio, 2009).

The moderating interaction between ACAP and external relationships on firm growth suggests that open innovation is not a static and isolated process. It interacts with a firm's organisational context, and is closely linked to firms' internal capabilities. Recent research however suggests that the process of open innovation is equally if not more important than its outcome (Spithoven et al., 2011; Parida et al., 2012; Robertson et al., 2012). This contrasts strongly with prior literature which overlooks the importance of the input and/or output of open innovation (Van de Vrande et al., 2009; Gassmann et al., 2010; Chesborough, 2006; Chesborough and Appleyard, 2007; Enkel et al., 2009). In fact, several studies have attempted to identify the important strategic aspects of open innovation, such as the roles of intermediaries (Lee et al., 2010; Wincent et al., 2009) and identification of commercial opportunities outside a SME's core business (Bianchi et al., 2010). A key area that receives increasing attention in recent studies in open innovation is the role of bi-directional capability-building in the open innovation process - which emphasizes the importance of a firm's ability to externalize internal knowledge (also called "outbound multiplicative capabilities"), as opposed to internalizing external knowledge (Gassmann et al., 2010; Hughes and Wareham, 2009). These outbound capabilities contribute to a firm's absorptive capacity (Henke, 2006), and allow the firm to maximize value capture across its boundaries (Hughes and Wareham, 2009). Thus, a thorough understanding of these key aspects would help future research better address the question of how to implement and profit from open innovation activities in SMEs.

Managerial implications

Our results suggest that managers could view their external relationships as a capability-enhancing activity. For most biopharmaceutical firms, exploratory relationships not only offer access to external new knowledge, but also provide opportunities for these firms to discover new insights which fit their existing practice. This process, therefore improves firms' ability to combine existing knowledge and newly-acquired and assimilated knowledge. However, it is worth-noting that some of the internal capabilities, e.g. realized absorptive capabilities, are unobservable. Thus, managers might not realize that other non-financial returns of external relationships, such as the enhancement of a firm's internal capability, exist alongside access to complementary sets of resources and assets.

Limitations and future research directions

One potential issue with these conclusions is that our analysis is based on the biopharmaceutical sector, a sector which is often regarded as having distinct characteristics. Some studies have suggested, however, that research results from biotechnology are generalizable to other high technology industries such as the telecommunications and semiconductor industries at least (Almeida, 1996). Before being confident about any generalization, however, other studies could usefully be undertaken in an attempt to generalize our results to other industries. Further exploration of EU-US contrasts within the biopharmaceutical sector would also be valuable. Studies might usefully identify the distinctive characteristics of the US and European biopharmaceutical firms and the different development paths of the biopharmaceutical industries within two unique innovation systems (Xia and Roper, 2009). Such comparisons might help to address long standing concerns in Europe about the underperformance of EU biopharmaceutical firms compared to those in the US in terms of innovation (Cooke, 2001; Taplin, 2007) and draw attention to the learning process by which these European biopharmaceutical firms are seeking to emulate their US counterparts. Another issue that we face here is the standard difficulty

of drawing causal inferences from cross-sectional survey data. A feasible avenue for future research could be to conduct longitudinal studies of the evolution and development of exploratory and exploitative relationships and dimensions of PACAP and RACAP over time. This would deepen our understanding of the dynamic relationship between PACAP/RACAP and openness and their potential links to firms' growth. Additionally, we acknowledge that the use of depreciated patent stocks (Park and Park, 2006) or citation weighted patents (Jaffe et al., 2002) could better capture the nature of firms' knowledge exploitation than patent counts, however due to data limitations, we have no information on individual patents or the timing of their award and so can neither apply depreciation rates or citation weights. Future research could gather more detailed information on each individual patent and or use alternative patent measures to verify the robustness of our finding.

Finally it is worth-noting that our data suggests that biopharmaceutical firms are shifting their attention towards exploratory (857) rather than exploitative relationships (652). This runs contrary to earlier studies which reported that exploitative relationships were tending to crowd out exploratory relationships (Rothaermel, 2001). One possibility is that as the biopharmaceutical industry is maturing, the dominance of exploitative relationships might be weakening as incumbents shift their attention towards exploratory relationships or in-house development (Zucker and Darby, 1997). The temporal dimension of such behavior in the biopharmaceutical industry is therefore also a potentially interesting focus for future research.

Table 1: Variable descriptives

Variable	All Firms (n=349)		EU (n=205)		US (n=144)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Openness						
No. of Exploratory Relationships	2.78	4.01	2.58	3.87	3.04	4.18
No. of Exploitative Relationships	2.10	6.47	2.03	7.05	2.18	5.64
PACAP Measures						
R&D Intensity	0.43	0.34	0.42	0.34	0.45	0.34
Employee Skills	0.69	0.28	0.67	0.29	0.71	0.26
Continuous R&D	0.87	0.34	0.86	0.35	0.88	0.33
RACAP Measures						
No. of Patents**	33.79	86.15	20.21	54.78	53.10	114.63
Growth						
Sales Growth	0.60	1.34	0.64	1.47	0.51	1.10
Firm Characteristics						
Firm Age**	13.60	12.41	12.10	11.53	15.90	13.30
No. of Employees**	47.00	84.04	35.00	68.01	65.00	101.25
Independent Company**	0.84	0.37	0.80	0.40	0.88	0.33
Main Markets						
Regional Market	0.76	0.43	0.75	0.44	0.78	0.41
Foreign Market	0.47	0.50	0.47	0.50	0.48	0.50
External Market*	0.32	0.47	0.27	0.44	0.40	0.49
Strategic Focus						
Basic R&D and Preclinical Dev.**	0.67	0.47	0.60	0.49	0.78	0.42
Clinical Trials (Phase I, II, III)**	0.38	0.49	0.26	0.44	0.55	0.50
Manufacturing*	0.52	0.50	0.47	0.50	0.58	0.50
Regulatory Support**	0.38	0.49	0.22	0.41	0.61	0.49
Marketing & Sales*	0.48	0.50	0.52	0.50	0.41	0.49

Notes: Asterisks indicate statistically significant differences in firm characteristics between the US and Europe on the basis of independent sample T tests: *denotesρ <0.05, **denotes ρ <0.01.

Source: Authors' Survey

Table 2: Variable correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Exploratory Relationships	1																		
2.Wrkforce R&D Engagement	0.144	1																	
3. Employee Skills	-0.002	0.264	1																
4. Continuous R&D	0.151	0.272	0.032	1															
5. No. of Patents Currently	0.080	0.032	-0.016	0.090	1														
6. Exploitative Relationships	0.062	-0.090	0.028	-0.120	0.052	1													
7. Sales Growth	-0.020	0.101	0.204	0.126	0.045	0.047	1												
8. Firm Age	-0.052	-0.370	-0.326	-0.010	0.217	-0.024	-0.156	1											
9. No. of Employees	0.023	-0.260	-0.262	0.096	0.456	0.069	-0.074	0.521	1										
10.No. of Employees Square	-0.013	-0.190	-0.173	0.070	0.448	0.015	-0.060	0.490	0.921	1									
11.Independent Company	0.019	0.149	0.203	0.086	-0.201	0.030	0.084	-0.368	-0.334	-0.303	1								
12. Regional Market	0.032	0.046	-0.028	0.036	0.001	-0.048	-0.085	0.041	0.015	0.035	0.047	1							
13. Foreign Market	-0.011	0.086	0.051	0.061	0.042	0.051	0.037	0.086	0.168	0.163	0.008	0.406	1						
14. External Market	-0.056	0.088	0.101	0.054	0.207	0.086	0.100	0.115	0.159	0.170	-0.037	0.192	0.601	1					
15.Basic R&D & Preclinical Dev.	0.186	0.291	0.151	0.211	0.251	-0.119	-0.058	-0.002	0.047	0.049	-0.091	-0.042	0.062	0.044	1				
16. Clinical Trials (Phase I, II, III)	0.100	0.145	0.014	0.097	0.337	0.032	0.051	0.046	0.107	0.021	-0.035	0.069	0.150	0.140	0.307	1			
17. Manufacturing	-0.117	-0.270	-0.172	-0.020	-0.040	-0.037	0.076	0.118	0.213	0.175	0.033	-0.020	0.136	0.083	-0.190	0.030	1		
18. Regulatory Support	0.033	-0.140	-0.026	0.015	0.218	0.121	-0.021	0.236	0.27	0.212	-0.078	0.046	0.069	0.180	0.123	0.390	0.154	1	
19. Marketing & Sales	0.100	-0.220	-0.014	-0.030	-0.099	0.128	0.163	0.054	0.065	0.094	0.025	0.064	-0.002	0.058	-0.210	-0.080	0.293	0.220	1

Notes: Correlations greater than 0.11 are significant at 10 per cent level. N=237.
Source: Authors' Survey

Table 3: Modelling openness and RACAP

Variable	Model 1 No. of Exploratory Relationships		Model 2 RACAP (No. of Patents)		Model 3 No. of Exploitative Relationships	
	Coef.	Z-stat	Coef.	Z-stat	Coef.	Z-stat
PACAP Indicators						
R&D Intensity	-0.059	-0.23				
Employee Skills	-0.643*	-2.36				
Continuous R&D	0.596**	3.49				
Openness						
Log (No. of Exploratory Relationships)			0.294**	2.63		
RACAP Indicators						
No. of Patents					0.003+	1.73
Firm Characteristics						
Firm Age	-0.011*	-2.07	0.014	0.96	-0.018	-1.63
No. of Employees	0.006+	1.74	0.011**	4.89	0.020**	5.48
No. of Employees Square	<0.001*	-2.17	<0.001**	-2.90	<0.001**	-5.81
Independent Company	-0.331	-1.23	-0.876*	-2.56	-0.099	-0.36
Main Markets						
Regional Market	0.103	0.58	-0.097	0.45	-0.103	-0.51
Foreign Market	0.041	0.21	-0.321	-1.57	0.475+	1.68
External Market	0.222	1.13	0.339+	1.79	0.347	1.07
Strategic Focus						
Basic R&D and Preclinical Dev.	0.352*	2.51	0.383+	1.68	-0.701*	-2.59
Clinical Trials (Phase I, II, III)	0.068	0.46	0. 930**	4.33	-0.101	-0.47
Manufacturing	-0.178	-1.05	-0.343+	-1.67	-0.226	-1.11
Regulatory Support	-0.324*	-2.08	0.330	1.56	0.056	0.30
Marketing & Sales	0.225	1.27	-0.306	-1.56	0.732**	3.58
Nationality (EU/US)	-0.071	-0.53	-0.348	-1.62	0.228	1.19
Constant	1.357***	3.18	2.731**	5.78	0.911**	2.04
Number of Observations	237		237		237	
Equation Wald-test $\chi^2(15, 17,14)$	40.10**		228.54**		62.89**	

Notes: Models are estimated by ZINB and individual survey responses are weighted to provide representative results. Significance is denoted as follows: +denotesρ <0.1, *denotesρ <0.05, **denotes ρ <0.01.

Source: Author's Survey

Table 4: Modelling business growth

Variable	Model 4 Log (Sales Growth) Coef.	Z-stat	Z-
Openness			
No. of Exploitative Relationships	0.011	0.74	
RACAP Indicators			
No. of Patents	0.082*	2.19	
No of Exploratory Relationships*	-0.009	-1.47	
Firm Characteristics			
Firm Age	-0.006*	-2.00	
No. of Employees	<0.001	-0.50	
No. of Employees Square	<0.001	0.61	
Independent Company	0.085	1.15	
Main Markets			
Regional Market	-0.011	-0.13	
Foreign Market	-0.030	-0.34	
External Market	0.149	1.62	
Strategic Focus			
Basic R&D and Preclinical Dev.	-0.116	-1.45	
Clinical Trials (Phase I, II, III)	-0.049	-0.59	
Manufacturing	0.018	0.29	
Regulatory Support	-0.052	-0.56	
Marketing & Sales	0.140*	2.12	
Nationality (EU/US)	0.083	1.07	
Constant	0.222	1.39	
Number of Observations	237		
Equation Wald-test $\chi^2(16)$	29.51*		

Notes: Models are estimated by truncated regression and individual survey responses are weighted to provide representative results. Significance is denoted as follows: $^{+}$denotes ρ <0.1, *denotes ρ <0.05.

* Here we use No of Exploratory Relationships as a control variable in the estimation.

Source: Authors' Survey

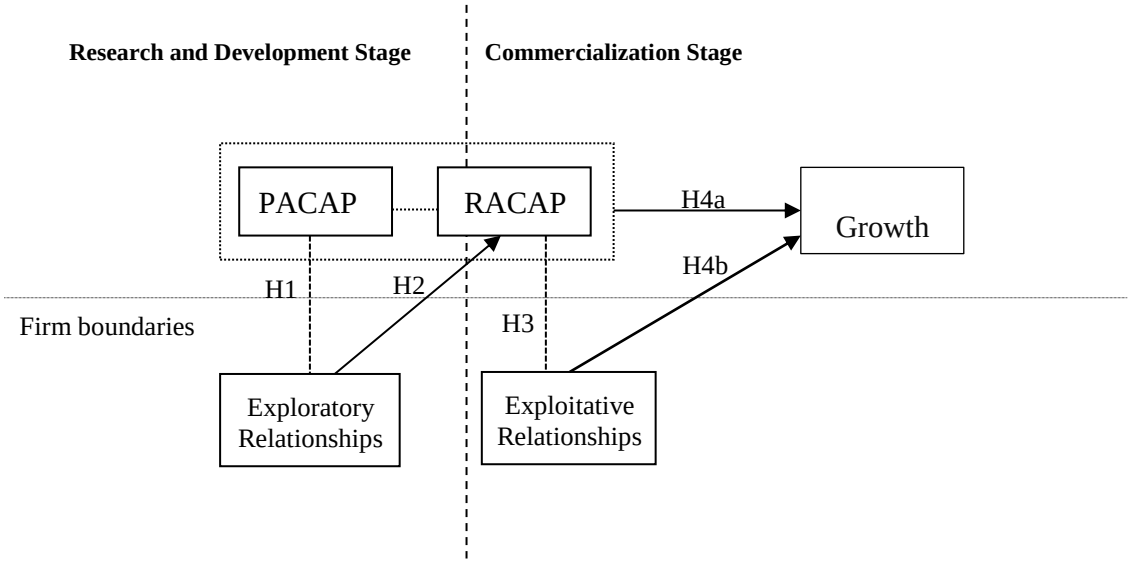
Table 5: Symbolic summary of estimation results

Variable	Exploratory Relations	RACAP	Exploitative Relations	Business Growth
	Equation (1)	Equation (2)	Equation (3)	Equation (4)
PACAP Indicators				
R&D Intensity	–			
Employee Skills	–			
Continuous R&D	(+)			
RACAP Indicators				
No. of Patents			(+)	(+)
Openness				
Exploratory Relationships		(+)		–
Exploitative Relationships				+
Firm Characteristics				
Firm Age	(–)	+	(–)	(–)
No. of Employees	(+)	(+)	(+)	(–)
No. of Employees Squared	(–)	(–)	(–)	(+)
Independent Company	–	–	–	+
Main Markets				
Regional Market	+	–	–	–
Foreign Market	+	(–)	+	–
External Market	+	(+)	+	+
Strategic Focus				
Basic R&D and Preclinical Dev.	(+)	(+)	(–)	(–)
Clinical Trials (Phase I, II, III)	+	(+)	–	+
Manufacturing	–	+	–	–
Regulatory Support	(–)	+	+	–
Marketing & Sales	+	(–)	(+)	(+)
Constant	(+)	(+)	(+)	(+)

Notes: Symbols not in parentheses are significant at more than 10% confidence level.

Source: Authors' Survey

Figure 1: Conceptual Framework



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