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Absorptive Capacity and External Technology Sourcing: Empirical investigation of vertical and horizontal relationships in the research and development process

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Absorptive Capacity and External Technology Sourcing: Empirical investigation of vertical and horizontal relationships in the research and development process[1]

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Abstract

Firms' decisions regarding external research and development (R&D) sourcing are influenced by their absorptive capacities, as developed through their internal R&D activities. However, it remains to be determined how the effects of absorptive capacity on firms' external sourcing strategies vary among the R&D stages, namely, upstream "research" or downstream "development" in the entire R&D process. Based on a detailed pharmaceutical R&D data set, which allows us to separately identify "research" and "development" activities, we have empirically investigated how the R&D process stage affects the relationship between internal R&D and external technology sourcing. Additionally, we separate efforts from capabilities for the concept of "absorptive capacity" to observe more precisely the aforementioned relationship between internal capacity and external technology sourcing. A complementary internal-external relationship is found more frequently for vertical looks ("R" and "D") and for internal "efforts," while some substitutional relationships exist between the research's internal "capabilities" and external sourcing (horizontal looks).

Keywords: Absorptive capacity, External technology sourcing, Research and development

JEL classification: O32; O31

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1. Introduction

Increasing market turbulence, volatile customer needs, and severe international competition urge firms to expand their R&D boundaries and to rely on external technology (Chesbrough, 2003). However, external technology sourcing is not only a substitute for internal technology development, and firms must make prior investments to prepare to exploit external resources. Specifically, they must develop a prior internal knowledge base, which helps them acquire, assimilate, transform, and exploit externally generated knowledge for innovation. This "absorptive capacity," in other words, is required for successful open innovation (Cohen & Levinthal, 1989). Many studies have illuminated absorptive capacity's important role in the alliance network to optimize the value of external knowledge (Lane et al., 2006; Tsai, 2001; Lin et al., 2012). Another string of studies has focused on firms' decision-making regarding externalization, and has investigated the relationship between the firm's level of absorptive capacity and their willingness to employ external R&D sourcing (Spithoven & Teirlinck, 2015; Zahra & George, 2002; Piga & Vivarelli, 2004; Becker & Dietz, 2004, Cassiman & Veugelers, 2006).

However, the aforementioned studies' empirical findings are inconsistent, as some suggest that a firm's absorptive capacity is a driver for its external sourcing (Caloghirou et al., 2004), while others contend that the absorptive capacity's effect is contingent, and can negatively impact a firm's external sourcing in certain conditions (Nooteboom et al., 2007). One reason for this inconsistency is the fact that existing literature uses an aggregated variable to conceptualize absorptive capacity, which includes multiple aspects with different impacts on firms' performance (George et al., 2001). One aspect involves whether absorptive capacity is measured by indicators of either "effort" or capability. Zahra and George (2002) distinguished the absorptive capacity (AC) concept from potential AC, or the acquisition and assimilation of external technology, and realized that AC, or the transformation and exploitation into an internal capacity, suggested different impacts on firms' performance. Empirically, some researchers use R&D expenditures or intensity as a proxy of absorptive capacity,

capturing the “effort” side of the concept (Arora & Gambardella, 1994; Cohen & Levinthal, 1990; Kim, 1999; Tsai & Wang, 2008; Caloghirou et al., 2004). Others use patent data for the same purpose (Mowery et al., 1996), which is associated more with a firm’s R&D capabilities rather than their efforts, because a patent represents the outcomes of the firm’s innovation activities. Recently, Srivastava et al. (2015) highlighted this issue and provided insightful implications regarding the different dimensions of absorptive capacity, or specifically, “effort” or “capability.”

Another reason for the inconsistency in empirical studies analyzing the relationship between internal R&D and external technology acquisition relates to the heterogeneity in R&D activities. It should be noted that “research” and “development” have significantly different purposes and consequences in terms of economic outcomes (Von Zedtwitz & Gassmann, 2002; Czarnitzki et al., 2009). “Research” is an activity that acquires new knowledge with less focus on its market application, while “development” is conducted for cultivating actual new products to be introduced in the market. When we decompose an entire R&D process into its upstream and downstream activities, the question of internal-external relationships in technology becomes one that questions the vertical and horizontal relationships between not only “research” and “development,” but also internal activities and external sources. Tackling this question is important, as most firms separately manage these two activities. A large corporation in such R&D-intensive sectors as the electronics, automotive, and pharmaceutical industries typically has an independent research function, such as a corporate research center, as well as development departments that conduct new product development activities. However, past literature has not investigated this question, to our knowledge.

We have studied in this paper the relationship between internal R&D and external technology sourcing by 2 x 2 dimensions, namely, “vertical” or “horizontal” in the R&D process, and “effort” or “capability” in internal absorptive capacity. We use the pharmaceutical industry for our test base, as research and development activities can be clearly defined in this industry, to construct a novel data

set consisting separately of both “effort” and “capability” variables in the “R” and “D” stages. Our primary focus is how internal effort and capacity in the “R” or “D” process leads to external sourcing in “R” or “D” to suggest how managers can properly balance internal and external activities given limited managerial resources. The remainder of the paper is organized as follows: Section 2 develops theoretical underpinnings based on related literature, which focuses on the effect of absorptive capacity and interplays between internal and external R&D. Section 3 presents the research methodology, including the data and variables. Section 4 provides the statistical analysis’ results, and Section 5 concludes and provides implications.

2. Theory and hypotheses

We build upon the work of Srivastava et al. (2015) by decomposing absorptive capacity into two dimensions: effort and capability. Additionally, we investigate the role of absorptive capacity derived from each dimension in the horizontal and vertical relationships between internal and external R&D. Figure 1 displays the conceptual framework, which illustrates the implications of existing research and the key focus of our research.

2.1. Research and development in the pharmaceutical industry

R&D activities include multiple steps, and each step requires different types of knowledge and expertise to achieve different objectives. According to the OECD’s Frascati Manual (2002), “R&D” consists of three activities: basic research, applied research, and experimental development. Basic research is defined as activities to acquire new knowledge without particular application or use in view, while applied research is a knowledge-acquisition activity with a specific practical aim or objective. Experimental development is defined as systematic work drawing on existing knowledge gained from research and/or practical experience.

Basic and applied research in the pharmaceutical industry can be obviously distinguished from experimental development by a regulatory requirement: investigational new drug (IND) application. The law requires drug makers to file an IND application before administering a drug candidate to human subjects in clinical studies. Basic and applied research, called an “upstream research phase” in this paper, is a pre-IND process characterized by science-driven activities, such as the discovery of target molecules that critically relate to particular diseases; or the identification of lead compounds and their evaluation in terms of efficacy, safety, and other various perspectives. Experimental development in the pharmaceutical industry, called a “downstream development phase” in this paper, is a post-IND process characterized by a different set of activities, such as an assessment of the appropriate patient population, clinical trial design, or the optimization of manufacturing processes.

The upstream research phase is an essential step for most research-intensive industries to generate innovation, which leads to firms’ core competence. The discovery of new chemical entities (NCEs) occurs at this phase in the pharmaceutical industry. The NCE’s profile determines the product’s overall potential as it is finally launched on the market, and key “substance” patents are filed immediately after the drug’s discovery.

Alternatively, as firms are urged to reinforce their pipeline assets across the entire R&D process, strategic alliances to acquire external R&D resources are formed at all R&D phases (Figure 1a). Firms create alliances not only in the early research phase to obtain platform technologies or new opportunities for drug discoveries, but also in the late development phase to replenish their deteriorating pipeline assets with externally generated drug candidates. Therefore, internal activities and external technology sourcing related to these activities are not always collectively localized in the same lengthy R&D process phase.

Therefore, it is important to consider whether internal R&D activities and external technology sourcing are located in the same phase (horizontal relationship) or in different phases (vertical

relationship) when absorptive capacity's role is examined. Existing studies conceptualize a firm's absorptive capacity by measuring the number of patents, R&D intensity or expenditures, and the number of employees, although these variables reflect multiple aspects of a firm's internal R&D activities and do not capture R&D at a particular phase (Tsai & Wang, 2008; Caloghirou et al., 2004; Mowery et al., 1996). Specifically, patenting activities occur in an earlier research phase, while R&D costs are disproportionally distributed toward late-development activities; thus, they observe different aspects of these R&D activities.

2.2. Efforts and capabilities as a source of absorptive capacity

Although absorptive capacity is unquestionably essential for firms to effectively acquire, assimilate, and exploit external knowledge, a question has yet to be answered regarding how internal R&D activities lead to the creation of a knowledge base, and function as a foundation of absorptive capacity (Cohen & Levinthal, 1990). Specifically, it is unclear whether internal R&D efforts are a sufficient factor per se to develop absorptive capacity, regardless of what is realized by the efforts, or how internal capabilities must be improved as a result of these efforts. One approach to this question involves decomposing the constituents of absorptive capacity into internal R&D efforts and capabilities. In fact, several researchers have adopted this approach; Kim (1999) suggests that the intensity of efforts is crucial for a firm's long-term learning and competitiveness, as this is essential to develop technological capabilities and absorptive capacity. Alternatively, Caloghirou et al. (2004) captured internal capabilities by the intensity of R&D efforts and highly qualified personnel, and demonstrated that both internal R&D capabilities and effort play a positive role in increasing innovative performance.

Recently research by Srivastava et al. (2015) provides meaningful insights with well-structured empirical analyses. The authors use distinct variables for a firm's technological efforts and capabilities,

respectively, to demonstrate that each element has a different moderating effect on absorptive capacity. Their finding parallels existing literature, to the extent that both efforts and capabilities have significant influences as sources of absorptive capacity. Their research is novel in that technological efforts and capabilities have opposing effects for firms to realize innovation benefits from their alliance network. The authors claim that technological efforts represent a firm's broad preparedness in understanding new technologies, and the firm's investments in their internal R&D further indicate such preparedness. Firms with stronger efforts increase the possibility of reaching out to explore external knowledge and realizing more benefits from their alliance network. Conversely, technological capabilities indicate a firm's past success. The authors argued and empirically proved that firms with strong technological capabilities are less willing to explore distant external knowledge, therefore achieving less innovation with their alliance networks.

As firms essentially invest in their own R&D activities to strengthen their capabilities to further innovate, it is noteworthy that capabilities inhibit innovation from the alliance network and its resources. It is important from a managerial perspective to know more about how capabilities inhibit innovation. We construct hypotheses in the next section based on the argument that these mechanisms depend on the relationship between internal R&D activities and external technology sourcing in the R&D process.

2.3. Hypotheses

The aforementioned extant literature offers theoretical insights by a detailed analysis of the different dimensions of absorptive capacity. We build upon their methodology by distinguishing a firm's internal R&D efforts and capabilities, and establish hypotheses based on absorptive capacity's role in firms' strategic external sourcing decisions.

2.3.1. Effect on absorptive capacity in the horizontal relationship

First, we focus on a case in which both internal and external R&D are in an upstream research phase. The R&D activities in such a horizontal relationship essentially pursue the same objectives, namely, the acquisition of new knowledge, and a complementary effect might exist between internal and external R&D. Therefore, firms with internal R&D activities may undertake more external technology sourcing with an expectation of complementarity. Alternatively, firms with internal R&D activities may be reluctant to acquire external R&D resources to avoid redundancy, if they regard internal and external R&D as substitutes. We argue that the key elements of internal R&D activities, or specifically, efforts and capabilities, affect a firm's decisions regarding external technology sourcing by influencing its perception of external R&D in terms of complementarity and its substitutability with internal R&D.

Srivastava et al. (2015) suggest that the "effort" dimension represents a firm's broader readiness to create new knowledge, and positively affects the exploration of external knowledge. Their study measured R&D using patent information and R&D intensity; this means that they captured aggregated R&D activities, as patents are filed at the upstream research phase, while R&D investments are disproportionately weighted toward the downstream development phase. We build upon their arguments and anticipate that the same positive effect on external sourcing can be observed even when we specifically focus on a horizontal relationship. The effect might be more prominent, as the knowledge base developed by internal research efforts can be directly utilized for external research when they are at the same phase.

Alternatively, Srivastava et al. (2015) argue that technological capabilities compel firms to be more inwardly focused, and create firms' internal resistance toward externally generated knowledge. We consider that such an internal resistance is enhanced in a horizontal relationship, in which internal and external R&D pursue the same objectives. Firms with stronger internal capabilities will place less

value on external R&D; thus, these firms are even less likely to substitute internal activities with external ones, and particularly when they are in the same R&D phases. Acquiring external R&D assets in addition to internal R&D is not efficient due to resource constraints, as firms must invest in not only internally generated research, but also in those that are externally acquired. In summary, the positive effect of internal efforts and the negative effect of internal capabilities on external technology sourcing, both of which were demonstrated by Srivastava et al. (2015), can be observed more prominently in a horizontal relationship. We establish the following hypotheses based on this argument:

Hypothesis 1. *Internal R&D efforts positively relate to external technology sourcing when internal and external R&D have a horizontal relationship.*

Hypothesis 2. *Internal R&D capabilities negatively relate to external technology sourcing when internal and external R&D have a horizontal relationship.*

2.3.2. Effect on absorptive capacity in the vertical relationship

Several studies examined the interaction of internal and external resources in a vertical relationship. Hess and Rothaermel (2011) suggest that resource combinations across firm boundaries are complementary when they are at the different parts of the value chain (vertical relationship), while they are substitutive at the same part. Another research study focusing on absorptive capacity's role in a vertical relationship demonstrates that vertical alliances, such as outsourcing and distribution agreements, positively relate to firm performance, and firms benefit from combining internal upstream efforts and external downstream resources (George et al., 2001). These findings imply that some interactions are fundamental between internal and external resources, even if they are in different R&D phases. We address this along the effort and capability dimensions, and provide theoretical insights regarding internal R&D's role in external technology sourcing in a vertical relationship.

While Srivastava et al. (2015) does not specifically address vertical relationships, they indicate

that internal technological efforts enhance a firm's willingness and capacity to search, value, assimilate, and deploy external knowledge. We claim that the latter two elements, assimilation and deployment, are critical factors for successful external sourcing, and particularly in a vertical relationship. Assimilation is a process to internalize external knowledge and integrate it with internal knowledge. Further, as Srivastava et al. (2015) argued, this would be more difficult when the external and internal knowledge is dissimilar. Such a dissimilarity increases when internal and external knowledge are in a vertical relationship, and knowledge is more difficult to deploy when it is constituted of internal and external knowledge at different phases. Internal efforts could assist firms in overcoming these challenges by enhancing the firm's assimilation and deployment abilities. Therefore, we argue that internal efforts positively impact external technology sourcing, even in a vertical relationship. This parallels an implication provided by Hess and Rothaermel (2011), which suggests that resource combinations are complementary when internal and external resources are at different value chains, and a marginal return to internal resources increases in the presence of external resources. These considerations lead to the following hypothesis:

Hypothesis 3. *Internal efforts positively relate to external technology sourcing when internal and external R&D have a vertical relationship.*

Next, we discuss the role of internal capabilities in a vertical relationship. Specifically, we focus on internal capabilities' effects in the upstream research phase on external technology sourcing at the downstream development phase. We anticipate that the role of internal capabilities in a vertical relationship would be more complex than that in a horizontal relationship because of the mixed effects of both positive and negative factors.

Higher capabilities at the research phase lead to more outcomes at the development phase, for

which firms subsequently make further efforts. Upstream capabilities, in other words, become the foundation of downstream efforts. As Hypothesis 1 claimed, a positive effect is anticipated between internal efforts and external sourcing at the same phase. Therefore, we argue that internal capabilities at the upstream research phase positively affect external technology sourcing at the downstream development phase.

Alternatively, it is likely that firms with high capabilities in the research phase also have high capabilities in the development phase. A negative effect is also anticipated in this regard, as we claim in Hypothesis 2 that internal capabilities negatively relate to external technology sourcing in a horizontal relationship. Overall, the effect of the firm's internal capabilities at the upstream research phase on external technology sourcing is determined by the balance between these opposing effects. We elucidate this overall effect by constructing the following alternative hypotheses:

Hypothesis 4a. *Internal capabilities positively relate to external technology sourcing when internal and external R&D have a vertical relationship.*

Hypothesis 4b. *Internal capabilities negatively relate to external technology sourcing when internal and external R&D have a vertical relationship.*

Finally, we further examine the aforementioned balance between positive and negative effects, in terms of the conditions that alter either of the opposing effects. Several studies imply that the effects of endogenous factors, such as internal capabilities, are moderated by exogenous factors, including market environments (Yoo et al., 2015; Danzon et al., 2005). Yoo et al. (2015) demonstrate that the effect of endogenous factors, such as ambiguity avoidance, organizational inertia, and absorptive capacity, on external sourcing decisions is moderated by exogenous factors, including competitive intensity and market turbulence. Danzon et al. (2005) indicate that more market entrants make R&D

more difficult, and urge firms to engage in more alliances. Further, Dranove and Meltzer (1994) demonstrate that firms accelerate R&D for a drug candidate that is more important and attractive in the market by using both internal and external resources. These findings suggest that market factors provide firms with incentives or challenges to tap into external technology sourcing.

Internal capabilities are closely linked to the development of ambiguity avoidance, organizational inertia, and absorptive capacity, which were studied by Yoo et al. (2015) as endogenous factors. Therefore, we build upon their implications by considering that market conditions play a crucial moderating role for internal capabilities. As already argued, firms with high capability have fewer incentives to access external knowledge, as they are more interested in internally generated knowledge, which they anticipate is superior to others. We suggest that this tendency is enhanced by higher market growth, as a "best mix" of high capability and strong market growth is likely to compel firms to be more inwardly focused. Whether internal capabilities' effects are positive or negative, in other words, this is downwardly moderated by market growth. Therefore, we offer the following alternative hypothesis based on this argument:

Hypothesis 5. *Firms with higher internal capabilities are less willing to engage in external technology sourcing when they are experiencing higher market growth.*

3. Methods

We first describe the data set and variables used in the empirical analysis, followed by information regarding the estimation methods and econometric specifications.

3.1. Sample

A panel data set from multinational pharmaceutical firms is used for the empirical analysis. We

collect R&D-related data using Thomson Cortellis, a comprehensive source of global pharmaceutical industry intelligence[2]. The database contains data from drug monographs, unique company profiles, patents, deals, and other information relating to drug discovery and development. The pharmaceutical industry provides an appropriate research context for our study due to the strong reliance on R&D and the prevalence of external partnerships.

Our research's key focus is internal R&D's effects on external technology sourcing in terms of horizontal and vertical relationships: how internal R&D conducted at a particular R&D phase influences firms' external sourcing strategies at the same or different phase. The majority of empirical studies in this arena do not address this issue, as specific relationships between internal and external R&D cannot be identified by the firm-year unit of analysis that these studies employ. Thus, it is necessary to establish a data set in which internal R&D is tied to its relevant external R&D resources as closely as possible. We design such a data set by collecting data on a market-by-market basis. Particularly, we collect all data from four representative therapeutic areas (diabetes, rheumatoid arthritis, hypertension, and depression), respectively, and construct a separate data set for each market. Therefore, our unit of analysis is a firm's behavior in a given market in a given year, and not a firm-year unit. It is unlikely that an internal R&D activity in a certain therapeutic area influences a firm's external sourcing decisions in other areas. We exclude such cases from our observations and focus on interactions in the same therapeutic area to observe more specific relationships between internal and external R&D in terms of R&D status. We select the aforementioned four representative therapeutic areas based on the following criteria: (1) at least half of sample firms invest in the therapeutic area, and (2) the therapeutic area is sufficiently distinct and does not include several types of diseases. According to the Anatomical Therapeutic Chemical Classification System, one of the most authorized

[2] "Cortellis Competitive Intelligence" by Thomson Reuters Professional KK. This dataset is subscribed by RIETI, which made available for our research project under RIETI

classifications of drugs, drug products are categorized under 14 classes. We do not adopt this classification as some classes have limited players, or different types of drugs are classified in the same categories (e.g., both anti-rheumatic and anti-osteoporosis drugs are classified as "musculoskeletal," although these differ in terms of their drug profiles and target populations).

External sourcing strategies substantially differ between large incumbents and small biotech firms. The former group is essentially equipped with their own internal R&D capacity, but utilizes external R&D resources to reinforce their productivity or replenish pipeline assets when they consider the internal pipeline insufficient for market competition. Alternatively, small biotech firms typically have only an upstream research capacity, and rely on the downstream capabilities of larger incumbents. Small firms' strategic behaviors are significantly distinct from our study's focus; thus, we exclude smaller firms from our research setting and focus on the world's top 22 pharmaceutical firms to correctly analyze the key determinants of firm behavior in the selected 4 markets. Data during 2000–2011 are collected, which constitutes a panel data set with 1,056 units of analysis.

3.2. Variables

Two dependent variables are used in our analysis: external sourcing at the upstream research phase (ExRes) and external sourcing at the downstream development phase (ExDev). We operationalize external sourcing at the upstream research phase using the number of patent applications that are jointly filed with third parties. The patent type is limited to "substance patents" to exclude patents related to inventions at later phases, such as formulation and manufacturing methods. External sourcing at the downstream development phase is operationalized by introducing a binary variable, which assumes a value of one if a focal firm acquires externally-generated compound(s) at the development stage in a given market in a given year, and zero otherwise. Only acquisitions of compounds in development through in-licensing are regarded as external sourcing in our analysis, and

corporate acquisitions are not included; as corporate acquisitions are conducted based on various reasons, the inclusion of such cases leads to misspecification.

One of the independent variables, internal R&D effort at the upstream research phase, is measured using a focal firm's number of internal research projects (IntR_Effort). The number of research projects is identified by drawing the number of target molecules identified in all patent applications filed by the firm. A pharmaceutical firm's research project is generally arranged by every target molecule, and the number of research projects in which firms invest their resources reflects the degree of their efforts.

We operationalize internal capabilities at the upstream research phase in this study by creating a unique variable (IntR_Cap), defined as the number of compounds for which a firm filed IND applications in year *t*, divided by the number of patent applications of the firm in year *t* - 3. Patent applications are used as a proxy for the new chemical entities (NCEs) designed by a firm. This unique variable represents the effectiveness in creating a compound that can pass the upstream research phase. A three-year lag is set to consider the time required to transform research efforts into successful IND filings, based on the industry average of the period from identifying a lead compound to its IND filing (Yagi et al., 2010; Paul et al., 2010). Figure 2 illustrates the relationship between internal efforts and capabilities in the pharmaceutical firms' R&D processes.

We introduce a variable related to market environments, in addition to the aforementioned independent variables, to observe market effects. Specifically, each market's growth rate is measured by using a three-year sales forecast in a given market (Mkt_Growth). The momentum of growth varies by market, and this alters firms' decisions regarding external sourcing (Dranove & Meltzer, 1994; Danzon et al., 2005; Yoo et al., 2015). Among the four areas in our research, the diabetes and rheumatoid arthritis markets are still expanding, and many new entrants are observed in the sample period, whereas the hypertension and depression markets are considered "genericized," and are

shrinking. We intend to capture this market dynamics effect with the (Mkt_Growth) variable, based on the premise that market growth might moderate a firm's decision regarding external technology sourcing (Hypothesis 5). Further, we introduce a binary variable to capture a firm's existing market presence (ExMkt), which assumes a value of one if a firm has one or more products with actual sales in a given market, and zero otherwise. Existing market presence helps firms avoid substantial investments to develop sales forces, supply chains, and other capabilities, which are required to enter a particular market from scratch. Our detailed data set allows us to use these market-related variables to extract firms' behavioral implications.

Other control variables are integrated in the estimations to examine the influence of other firm-specific and environmental factors. A firm's propensity for internal and external R&D may also act as a function of firm size; therefore, we control for this firm-specific factor by incorporating a firm's sales volume in a given market and year as a proxy of firm size. The R&D spending divided by total sales is introduced to control for the firm's propensity for R&D. Additionally, the total number of target molecules that firms pursue for drug discovery substantially varies in each market. This affects a firm's decision-making regarding internal and external R&D investments because it determines each market's technological opportunities. Therefore, the effect of technological opportunities is controlled by a variable (TechOpp), defined by the number of new target molecules identified in all patent applications filed in the last three years. Dummy variables are included to control for year-specific and other market-specific factors. Table 1 notes the variables used in this study.

3.3. Estimation methods

We estimate the effect of internal R&D efforts and capabilities on external research sourcing (horizontal relationship) by using panel data negative binomial regression, considering that the dependent variable (ExRes) is a non-negative integer value. A Poisson regression model is not

employed as an estimation method due to over-dispersion. An estimation of the effect of internal efforts and capabilities on external development sourcing (vertical relationship) is obtained by using a logit regression model on the panel data, as the dependent variable (ExDev) is a binary variable. Random effect models are adopted for both estimations based on Hausman's test.

4. Results

Table 2 reports the linear correlation among the independent variables. No variable, other than the value for the correlation between (Mkt_Growth) and (TechOpp), has a correlation factor greater than or equal to 0.5. A relatively high correlation between (Mkt_Growth) and (TechOpp) indicates that scientific advances create opportunities for new product development, thus driving market growth to an extent.

Table 3 reports the results of the negative binomial regression models, which analyze the effects of internal efforts and capabilities at the upstream research phase on external sourcing at the same phase (horizontal relationship). Model 1 is a basic model containing only the control variables. As prior research indicates, the effect of market growth is positive and significant, implying that firms rely more on external resources for R&D as markets grow and become competitive (Yoo et al., 2015). Firm size is also positively associated with external sourcing, consistent with prior findings (Berchicci, 2013). The effects of internal efforts at the upstream research phase are positive and significant in Models 2 and 4, which supports Hypothesis 1.

We posit that internal capabilities are negatively associated with external sourcing in a horizontal relationship; the knowledge base developed by internal capabilities increases the substitutability between internal and external R&D. As a result, firms with higher capabilities engage in less externalization. As the coefficients of internal capabilities in Models 3 and 4 are negative and significant, the results support Hypothesis 2.

Hypothesis 3 predicts that a firm's internal efforts in the upstream research phase positively relate to external sourcing at the downstream development phase (vertical relationship). Although internal R&D efforts at the upstream research phase are distant, and no direct interaction occurs with external R&D at the downstream development phase, we predict a positive relationship due to the complementarity between them. Table 4 presents the results of the logit regression models that address this hypothesis. All models indicate significantly positive results, which include internal efforts as an independent variable (Models 2, 4, 5, and 6). Therefore, Hypothesis 3 is supported.

We construct the alternative Hypotheses 4a and 4b based on the premise that internal capabilities have both positive and negative effects on external technology sourcing decisions in a vertical relationship. Additionally, we argue that the effects of internal capabilities, whether overall positive or negative, are downwardly moderated by market growth (Hypothesis 5).

The coefficient of internal capabilities is not significant in Model 3. However, Model 6 includes an interaction term between internal capabilities and market growth, and the coefficient is subsequently both positive and significant. Model 6 also reveals a negative, significant coefficient for the interaction term, indicating that the positive effect of internal capabilities is negatively moderated by market growth. The coefficient of internal capabilities' insignificance when the interaction term is not included in Model 3 is rationalized by market growth's negative moderating effect; the primary effect of internal capabilities is offset by this effect. Therefore, Model 6 supports Hypotheses 4a and 5, respectively. Figure 3 depicts the interaction's isolated effects; the graph suggest that firms with higher internal research capabilities are more active in external development sourcing than those with lower capabilities when a market is experiencing low growth, but are less active in high-growth markets.

We introduce an interaction term between internal efforts and market growth in Model 5. Contrary to internal capabilities, the interaction term is not significant, which indicates that market

growth does not moderate internal effort's role in a vertical relationship. A positive and significant effect for (ExMkt) in all models is consistent with prior findings, which suggest that firms adopt different externalization strategies depending on whether they already have an existing market presence (Gilley & Rasheed, 2000).

5. Discussion

The conceptual framework provided by existing research offers a foundation by which we dichotomize the source of absorptive capacity into internal efforts and capabilities, and analyze each function in a firm's external sourcing decisions. Additionally, we add a new dimension to existing research by dividing the R&D process into research and development phases, and investigating the roles of efforts and capabilities in horizontal and vertical relationships between internal and external R&D. Although past empirical research indicates the importance in distinguishing the "R" and "D" in R&D (Czarnitzki et al., 2009), absorptive capacity's role has never been examined in a detailed research setting, to our knowledge.

Another remarkable approach in our study is that we collect data on a market-by-market basis. We focus on internal and external R&D conducted in the same therapeutic areas to better observe the influence of internal R&D, conducted at a certain phase, on external sourcing at a different phase. This data set also helps us investigate market-specific factors' effects on firms' external sourcing decisions.

Our research regarding internal efforts finds that this is positively associated with external sourcing in a horizontal relationship, consistent with the implications from Srivastava et al. (2015), which demonstrate technological effort's positive, moderating role in realizing the innovation benefits from alliance networks.

It is noteworthy that our study indicates that internal efforts also positively affect external sourcing even in a vertical relationship, in which internal efforts are made at the upstream research

phase, and external R&D resources exist at the downstream development phase. In other words, resource combinations across firm boundaries are facilitated, even when these resources are in a different phase. This result parallels prior research, in that internal and external resources are complementary when they are located at different parts of the value chain (Hess & Rothaermel, 2011). Hess and Rothaermel (2011) suggest that in such a vertical relationship, internal and external resources in different parts of a value chain can be effectively combined, as knowledge redundancies can be avoided. Another prior study demonstrates that vertical alliances positively relate to a firm's innovation performance (George et al., 2001). The study's authors claim that firms with core competencies at the upstream phase can concentrate investments in their competency by effectively using external downstream resources. Such a complementary relationship could drive a firm's vertical alliances (Cohen & Levinthal, 1989; Hagedoorn, 1993; Cassiman & Veugelers, 2006).

We demonstrate that internal capabilities at the upstream research phase are negatively associated with external sourcing at the same phase, which further indicates that the implication provided by Srivastava et al. (2015) is applicable in a horizontal relationship. However, this is not the case when internal and external R&D are in different R&D phases. The primary effect of internal capabilities is positive and significant in such a vertical relationship (Hypothesis 4a).

Internal capabilities have both positive and negative effects on external sourcing in vertical relationships. These capabilities intrinsically contribute to create a knowledge base, as certain advanced knowledge is only obtained when firms successfully advance their internal R&D to a higher stage. For example, firms with capabilities to develop a pharmacologically active compound as a drug candidate have the opportunity to explore the target diseases' biological mechanisms by experimenting on the compound, while firms without such capabilities are not eligible for such a learning opportunity. Moreover, higher capabilities at the upstream research phase are linked to more outcomes, in which firms will subsequently invest more effort. As these efforts positively relate to external sourcing,

internal capabilities at the research phase can lead to more external sourcing at the development phase. Additionally, firms must effectively deploy R&D resources distributed across firm boundaries to optimize efficiency and increase overall productivity in the R&D process (Chesbrough, 2003). Resource deployment requires specific skill sets, and the level of deployment ability determines a firm's external sourcing strategies. Srivastava et al. (2015) suggested that deployment capability can be enhanced by both effort and capability. These theories support the positive effect of internal capabilities in a vertical relationship.

However, higher capabilities compel firms to focus inwardly, which leads to less external sourcing (Song & Shin, 2008; Berchicci, 2013). The knowledge base created as a result of internal capabilities is considered firm-specific and less compatible with external knowledge; therefore, this may increase the substitutability between internal and external R&D (Higgins & Rodriguez, 2006; Berchicci, 2013). Higher capability firms, in other words, are less interested in sourcing external R&D. As internal research is more cost-effective than external sourcing in terms of transaction cost economics, firms with high innovation capabilities are less willing to undertake external sourcing (Ceccagnoli et al., 2010). These implications from prior articles corroborate the negative effects of internal capabilities in a vertical relationship.

Our study supports Hypothesis 4a by demonstrating that internal capabilities' positive effect outweighs its negative effect. When internal R&D and external knowledge of interest are in a vertical relationship, issues from the conflicts and redundancy between them as well as the negative effects of these issues are relatively small. Namely, firms with high capabilities in certain phases of their R&D processes may build an internal resistance toward external R&D at the same phase, but such resistance will not impact external R&D at a different phase. Further, as George et al. (2001) suggested, firms with core competence at a particular phase may opt to outsource external competence at different phases to concentrate investments in their competence under resource constraints. This might be an

underlying reason why internal capabilities have different effects depending on the relationships with external R&D.

Internal capabilities' positive effects in a vertical relationship are diminished by market growth (Hypothesis 5). This result mirrors prior research by demonstrating that market factors are critical to a firm's innovation strategy (Gunther McGrath & Nerkar, 2004; Danzon et al., 2005; Yoo et al., 2015). Market growth's moderating effect indicates that firms that possess higher capabilities in a growing market are less willing to implement external technology sourcing. Firms in such a condition, in other words, have fewer incentives to utilize their absorptive capacity for external sourcing and rely on internal R&D. This can be rationalized in terms of dynamic capability perspectives. Specifically, absorptive capacity is recognized as a dynamic capability as mentioned in existing literature (Zahra & George, 2002), and this dynamic capability includes the ability to exploit internal and external firm-specific competences to address changing environments (Teece et al., 1997). Firms with high capabilities in a growing market are the most stable and experience no urgent need to change; thus, they do not have to use absorptive capacity to exploit external knowledge.

This study only focuses on the instance that internal efforts and capabilities are at the upstream research phase. Internal efforts and capabilities at the downstream development phase may also particularly impact a firm's external sourcing strategies; thus, an avenue for further research exists that can be explored by the appropriate variables used to operationalize internal development activities. The number of clinical trials for internally generated compounds in a particular market might constitute a variable used to conceptualize development efforts. The stage-up ratio in clinical trial phases could be used to capture development capabilities.

Our study focuses on firms' behaviors in choosing external R&D resources in a relationship with internal R&D in terms of the absorptive capacity theory. Although absorptive capacity is a well-known factor that affects firms' external sourcing strategies, other theoretical perspectives should also

considered for a more comprehensive understanding of firms' choices between internal and external R&D. Transaction cost economics is one example, as a critical factor in firms' decisions when they enter into partnerships (Williamson, 1989). The apprehension regarding a "lemon" problem can deter firms from exploring external opportunities (Akerlof, 1970; Pisano, 1997). More complicated aspects of the relationship between internal and external R&D might be elucidated by considering this issue.

Further, we primarily direct our contributions toward firms' behavioral implications. We must extend internal and external R&D relationships to their outcome, namely, firms' innovation performance, to draw more managerial or political implications.

Finally, it is unclear as to whether these findings can be generalized across industries. Some of our study's results could be attributed to particular characteristics of the pharmaceutical industry: research intensity, a lengthy R&D process, and low success ratio. Further research in other industries is expected to generate more insight.

Despite the aforementioned limitations, our study significantly contributes to the identification of firms' unaddressed behavioral features in internalization and externalization strategies. We hope that these findings and implications will provide a basis for further research.

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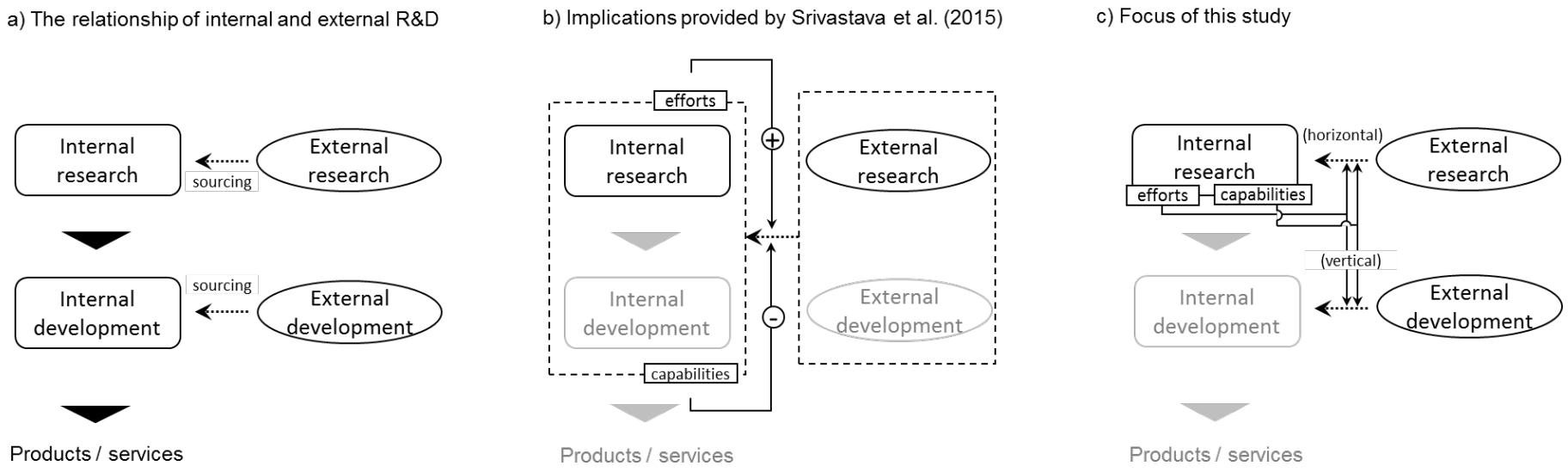

Fig. 1 Conceptual framework and hypotheses

(a) Incumbent firms possess their own internal R&D resources, but acquire external R&D resources to reinforce their R&D productivity. External sourcing is conducted at both the upstream research and downstream development phases. (b) Srivastava et al. demonstrated the positive effect of internal effort, and the negative effect of internal capabilities, on innovation from the alliance networks' resources. As their data set does not distinguish between the upstream and downstream phases, they indicated this relationship between internal and external R&D in its entirety. (c) Our study advances the implications provided by Srivastava et al. (2015) by focusing on absorptive capacity's role, as developed through the upstream research phase in firms' decisions regarding external sourcing at this phase (horizontal looks) as well as in the downstream development phase (vertical looks).

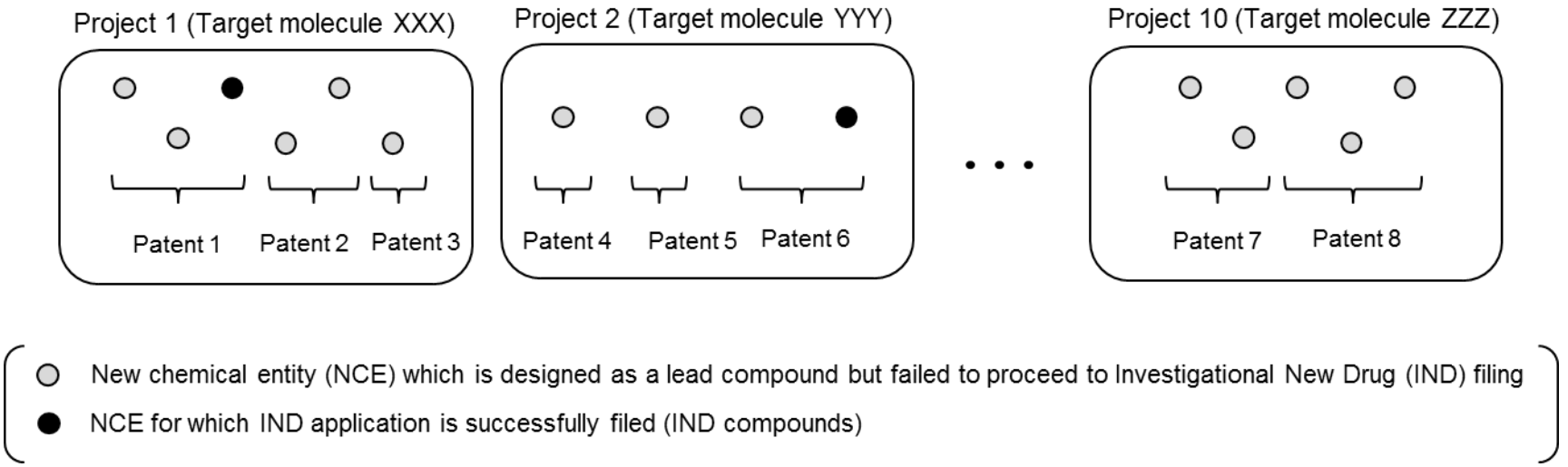

Fig. 2 The relationship between internal effort and capabilities in pharmaceutical R&D

The figure illustrates research projects in a pharmaceutical firm and their outcomes to illustrate how variables of internal effort and capability are designed. Research projects in the pharmaceutical industry are established by target molecules (e.g., the Angiotensin receptor or Dipeptidyl peptidase-4). New chemical entities (NCEs) are designed as drug candidates, and a few eventually proceed to Investigational New Drug (IND) applications. Patents are filed for these NCEs, and NCEs with similar chemical structures are claimed in the same patent (Patents 1, 2, 6, 7, and 8). Internal effort in this case (IntR_Effort) is measured by the number of projects (10). The IntR_Cap (internal capability variable) is 0.25, calculated by dividing the number of IND compounds (2) by the number of total patents (8). The total number of NCEs should be placed in the denominator, but we use the number of patents as a proxy due to data restrictions. A three-year lag is established between the patent's filing and the compound's status, based on the average research period.

Table 1

List of variables

Variable	Description	Empirical measurement	Value	Mean	S.D.
External R&D sourcing					
ExRes	External research sourcing	Number of patent applications which include applicants other than a focal firm	Count	4.644	8.047
ExDev	External development sourcing	1: sourcing for external compound(s) in development, 0: otherwise	Nominal	0.160	0.367
Internal research					
IntR_Effort	Internal research efforts	Number of internal research projects	Count	23.401	28.083
IntR_Cap	Internal research capabilities	The ratio of IND compounds per projects	Metric	0.207	0.460
Market conditions					
Mkt_Growth	Competitive intensity	a 3-year sales forecast in a given market	Metric	32.818	44.884
ExMkt	prior experience of the market	1: a firm has one or more products in a market, 0:otherwise	Nominal	0.502	0.500
Control variables					
Size	Firm Size	Firm's total sales	Metric	21.448	15.573
RDInt	R&D intensity	R&D spending divided by the total sales	Metric	0.140	0.056
TechOpp	Opportunities to explore new target molecules	Number of newly identified molecules in the last 3 years	Count	155.771	145.454
YearDum	Year dummy	N.A.			
MarkDum	Market dummy	N.A.			

Table 2

Pairwise correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
IntR_Effort (1)	1.00						
IntR_Cap (2)	-0.08	1.00					
Mkt_Growth (3)	0.29	-0.03	1.00				
ExMkt (4)	0.06	0.10	-0.07	1.00			
Size (5)	0.30	0.08	-0.18	0.21	1.00		
RDInt (6)	-0.09	0.09	-0.17	-0.03	-0.10	1.00	
TechOpp (7)	0.14	0.05	0.50	-0.03	0.06	0.06	1.00

Table 3

The effect of internal research effort and capability on external research sourcing

Negative binomial regressions

	Model 1	Model 2	Model 3	Model 4
Dependent variable	ExRes	ExRes	ExRes	ExRes
IntR_Effort		0.0105*** (0.0008)		0.0103*** (0.0008)
IntR_Cap			-1.3251** (0.5254)	-0.9113** (0.4954)
Mkt_Growth	0.0035*** (0.0010)	0.0015* (0.0008)	0.0037*** (0.0010)	0.0017** (0.0008)
ExMkt	0.1501* (0.0871)	0.1017 (0.0819)	0.1524* (0.0876)	0.1014 (0.0820)
Size	0.0152*** (0.0038)	0.0158*** (0.0034)	0.0153*** (0.0038)	0.0159*** (0.0034)
RDInt	0.0212 (0.6061)	-0.6110 (0.6095)	-0.0349 (0.6101)	-0.6377 (0.6084)
TechOpp	0.0001 (0.0001)	0.0003*** (0.0001)	0.0001 (0.0001)	0.0003*** (0.0001)
YearDum	Yes	Yes	Yes	Yes
MarkDum	Yes	Yes	Yes	Yes
Log likelihood	-2106.77	-2027.60	-2103.40	-2025.86
Chi-square	255.84***	536.12***	264.81***	566.58***

*p<0.1, **p<0.05, ***p<0.01

Table 4

The effect of internal research effort and capability on external development sourcing

Panel data logit regression

Dependent variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	ExDev	ExDev	ExDev	ExDev	ExDev	ExDev
IntR_Effort		0.0078**		0.0078**	0.0138**	0.0076*
		(0.0039)		(0.0039)	(0.0062)	(0.0039)
IntR_Cap			-0.0659	0.3387	0.2753	5.1707**
			(2.1845)	(2.1814)	(2.1816)	(2.6289)
Mkt_Growth	0.0028	-0.0019	0.0028	0.0019	0.0043	0.0058
	(0.0049)	(0.0049)	(0.0049)	(0.0049)	(0.0053)	(0.0052)
ExMkt	0.9101***	0.8989***	0.9112***	0.8933***	0.8726***	0.9151***
	(0.2477)	(0.2404)	(0.2506)	(0.2426)	(0.2438)	(0.2442)
Size	0.0365***	0.0304***	0.0365***	0.0304***	0.0286***	0.0303***
	(0.0085)	(0.0088)	(0.0085)	(0.0088)	(0.0090)	(0.0089)
IntR_Effort×Mkt_Growth					-0.0001	
					(0.0001)	
IntR_Cap×Mkt_Growth						-0.1377**
						(0.0592)
RDInt	1.0331	0.6566	1.0308	0.6646	0.4836	0.3430
	(2.2031)	(2.2896)	(2.2049)	(2.2889)	(2.3172)	(2.3217)
TechOpp	0.0011*	0.0011*	0.0011*	0.0011*	0.0010	0.0011*
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
YearDum	Yes	Yes	Yes	Yes	Yes	Yes
MarkDum	Yes	Yes	Yes	Yes	Yes	Yes
Log likelihood	-387.17	-385.29	-387.18	-385.28	-384.50	-381.78
Chi-square	80.98***	88.04***	80.93***	88.38***	88.00***	90.86

*p<0.1, **p<0.05, ***p<0.01

Fig. 3

Interaction between internal research capabilities and market growth