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Unpacking performance benefits of innovation ambidexterity: Evidence from the pharmaceutical industry [**]

Scholars argue that there is a positive relationship between organizational performance and simultaneous pursuit of exploitation and exploration, or organizational ambidexterity. However, prior work on performance benefits enabled by organizational ambidexterity does not separately examine two distinct mechanisms underlying this positive relationship. Our manuscript advances the literature on organizational ambidexterity by explicating the difference across alternative complementary relationships between exploitative innovation and exploratory innovation, namely a mutually compensatory relationship and a mutually enabling relationship. Our empirical analysis of 50 pharmaceutical firms' degree of innovation ambidexterity and subsequent firm performance supports the argument. Our findings provide us a more detailed anatomy of mechanisms in which ambidexterity enables favorable organizational performance.

Key words: **ambidexterity, innovation, exploitation, exploration, organizational learning** (JEL: L25, L65, M10, O32)

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1. Introduction

Innovation, or new technology-based products development in particular, is one of the most influential explanatory variables for favorable organizational performance in our age. However, this does not mean that we can explain organizational performance by solely considering innovation enabled by findings of revolutionarily new technological knowledge (henceforth, we refer to such innovation as exploratory innovation). Conversely, innovation enabled by new applications of existing technological knowledge (henceforth, exploitative innovation) also influences organizational performance substantially. For example, customers expect firms to innovate incrementally by exploiting existing technological knowledge, rather than by exploring novel technological knowledge (Christensen & Bower, 1996). Firms may also choose to forego opportunities to explore new product technology because their suppliers and distributors support exploitation of existing product technology (Glasmeier, 1991). Accordingly, the importance of simultaneously pursuing exploratory as well as exploitative innovation is underscored by recent research on organizational ambidexterity (O'Reilly & Tushman, 2008, among others).

Prior work on organizational ambidexterity uncovers performance benefits enabled by organizational ambidexterity with respect to various organizational aspects, including product configuration (Salvador, Chandrasekaran, & Sohail, 2014), modes of operation (Stettner & Lavie, 2014), innovation strategy (Cao, Gedajlovic, & Zhang, 2009; Derbyshire, 2014; He & Wong, 2004; Lubatkin, Simsek, Ling, & Veiga, 2006), search behaviors (Wang & Li, 2008), firm or business-unit contexts (Chang, Yang, & Chen, 2009; De Clercq, Thongpapanl, & Dimov, 2013; Gibson & Birkinshaw, 2004; Patel, Messersmith, & Lepak, 2013), organizational design (Adler, Goldoftas, & Levine, 1999; Chang et al., 2009), as well as founding team's prior affiliations (Beckman, 2006).

However, the prior research neglects to explicitly distinguish two distinct mechanisms in which organizational ambidexterity enables favorable organizational performance as it does not separately examine differences between two alternative complementary relationships between exploitation and exploration (Gupta, Smith, & Shalley, 2006; Katila & Ahuja, 2002). We refer to the two complementary relationships as a mutually compensatory relationship and a mutually enabling relationship, respectively. The former refers to a relationship in which exploitation and exploration mutually compensate for each other's deficiencies, in that they contribute to organizational performance in distinct, but mutually complementary ways. Put differently, exploitation's effects on organizational performance complement exploration's effects, and *vice versa*. On the other hand, in a mutually enabling relationship, exploitation and exploration mutually seeds and primes each other. More precisely, acts of exploitation complement acts of exploration by enabling the latter, and *vice versa*.

It is of theoretical as well as practical importance to take into account the differences between these alternative complementary relationships because they offer distinct explanations on the way in which ambidexterity enables favorable organizational performance. In addition to the locus of complementarity (i.e., effects or acts) and the mechanisms of performance benefits (i.e., compensatory or enabling), the two alternative complementary relationships also differ in their influences on the negative externalities between exploitation and exploration (Boumgarden, Nickerson, & Zenger, 2012). Furthermore, their differences inform us two distinct research directions for pursuing ambidexterity antecedents.

In this manuscript, we aim to fill this research gap by unpacking two alternative complementary relationships between exploitation and exploration, thereby arguing that organizational ambidexterity with respect to product innovation is positively associated with organizational performance in two distinct mechanisms. Therefore, our aim is to further our understanding of organizational ambidexterity by proposing two related, but distinct perspectives to explain its performance benefits, as well as to pursue its antecedents. Leveraging unique data on 50 pharmaceutical firms' new product innovation and subsequent firm performance, we provide empirical evidences for our argument.

2. Theory and hypothesis

2.1 Exploitation, exploration, and organizational ambidexterity

Organizational ambidexterity is an organizational capability to exploit internal knowledge while simultaneously exploring external knowledge (O'Reilly & Tushman, 2008; Raisch, Birkinshaw, Probst, & Tushman, 2009; Raisch & Birkinshaw, 2008). The concept of organizational ambidexterity is originally proposed by Duncan (1976), who characterizes the ambidextrous organization as an organization that sequentially shifts organizational structures as it moves through distinct stages of innovation, including the initiation stage and the implementation stage. Such adjustments to changing competitive requirements are called adaptation, which plays central roles in complex systems' performance optimization (Holland, 1975). Holland (1975) particularly emphasizes the importance of balancing "the efficient use of information and capabilities already available (p.181)" and "acquisition of new information and capabilities (*ibid.*)" despite their mutually contradictory nature.

Extending Holland (1975) and others, March (1991) applies these two modes of adaptive behaviors to the context of organizational learning, and contrasts them as exploitation and exploration. Exploitation is usually related to improvements, increased efficiency, and incremental adjustments, whereas exploration is closely linked with variety generation, distinctly new possibilities, distant search, and radical or revolutionary change (March, 1991). For example, in the context of technological innovation, scholars distinguish exploitation and exploration by considering whether the locus of organizational learning is on reusing existing knowledge and technology, or on pursuing new knowledge and technology. Accordingly, scholars operationalize exploitation and exploration with such polarized comparisons as pharmaceutical products based on existing chemical entities versus the ones based on new chemical entities (Bierly & Chakrabarti, 1996; Cardinal, 2001; Dunlap-Hinkler, Kotabe, & Mudambi, 2010), self-citing patents versus non self-citing patents (Benner & Tushman, 2002; Sørensen & Stuart, 2000), refinements of a CISC architecture microprocessor versus a shift to a RISC architecture microprocessor (Lee, Lee, & Lee, 2003), or refinement of existing hard disk drive form factors (operationalized by disk sizes) versus development of new form factors (Piao, 2010).

Although organizational survival and prosperity require simultaneous pursuit of exploitation and exploration (March, 1991), they are contradictory to each other. Organizations generally adopt distinct sets of organizational design elements (regarding structure, incentives, and culture) targeted to achieve either exploitation or exploration, but not both (Jansen, Van Den Bosch, & Volberda, 2006). Put differently, there are negative externalities between organizational design for exploitation and for exploration (Boumgarden, Nickerson, & Zenger, 2012). Scholars have shown that the organizational designs that promote exploitation are centralized, formalized, authoritarian, and mechanistic, while those that promote exploration are decentralized, flexible, autonomous, and organic (Abernathy, 1978; Burns & Stalker, 1961; Cyert & March, 1963; Duncan, 1976; McGrath, 2001; March, 1991). Because organizational design elements that deliver exploitation detract from the effectiveness of organizational design elements targeted to generate exploration, and *vice versa*, simultaneous pursuit of both diminishes firms' capacity to explore as well as exploit (Boumgarden, Nickerson, & Zenger, 2012; O'Reilly & Tushman, 2008).

Accordingly, further understanding of organizational ambidexterity calls for careful examinations of mechanisms in which organizations benefit from complementary relationships between exploitation and exploration by overcoming the negative externalities between the two sets of organizational design elements. We follow the prior work to specify organizational ambidexterity in the context of product innovation as "innovation ambidexterity," or a simultaneous pursuit of exploitative innovation and exploratory innovation. Following March (1991), we adopt organizational learning perspective to define exploitative innovation as an act of leveraging existing technological knowledge, designs, and mechanisms for new product applications, while exploratory innovation is innovation enabled by findings of novel technological knowledge, designs, and mechanisms (March, 1991). Below, we build on two dimensions of ambidexterity (Cao et al., 2009) and develop our hypotheses on two distinct mechanisms in which innovation ambidexterity enables favorable organizational performance in a related, but conceptually distinct manners.

2.2 Mutually compensatory relationship between exploitative and exploratory innovation

As discussed above, March (1991) originally characterizes exploitation and exploration as mutually exclusive forms of organizational learning. However, organizations need to pursue both exploitative and exploratory innovation to survive and prosper (Levinthal & March, 1993; March, 1991, p. 71), because organizations gain from exploitation and exploration in different yet complementary ways. For example, successfully surviving firms go through waves of product lifecycles by reciprocating between exploitative innovation and exploratory innovation (Abernathy & Clark, 1985; Henderson, 1995; Utterback & Abernathy, 1975). Likewise, successful dominant designs emerge when firms leverage existing technological knowledge by simultaneously pursuing novel technological designs, or product architectures that creatively synthesize the existing knowledge (Abernathy & Utterback, 1978; Clark, 1985;

Henderson & Clark, 1990). Therefore, exploitative innovation and exploratory innovation compensate for deficiencies of each other, and enable firms to closely adapt their products or services to the changing competitive landscape.

We refer to this aspect of the complementary relationship between exploitation and exploration as a mutually compensatory relationship because exploratory innovation compensate for lack of novelty associated with exploitative innovation, while exploitative innovation compensate for lack of certainty associated with exploratory innovation. Put differently, the locus of complementarity is performance effects of the alternative innovation, because it is effects of exploration that complement effects of exploitation, and *vice versa*.

When a firm develops its new products by only leveraging existing technological knowledge, designs, and mechanisms, the competition would quickly obsolete the firm's new products (Abernathy, 1978; Foster, 1986; Tushman & Anderson, 1986). On the other hand, by exploring novel technological knowledge, designs, and mechanisms, firms are able to better prepare themselves for uncertain future changes in their customers' needs or in competitive requirements. For example, new product development projects are instrumental in generating new capabilities and competency, effectively alleviating the threats of core rigidity (Leonard-Barton, 1992). Firms can also be more proactive by leveraging exploratory innovation as a means of creating (rather than reacting to) changes for their benefits. For instance, exploratory market learning gained through new product development is positively associated with the degree of product differentiation (Kim & Atuahene-Gima, 2010).

In spite of the expected benefits derived from such flexibility, exploratory innovation is associated with substantial technological as well as commercial uncertainty (March, 1991). Therefore, firms compensate for the risk of exploratory innovation by involving themselves in more certain and reliable exploitative innovation. It is because exploiting existing technological knowledge, designs, and mechanisms accumulated through preceding product innovation is a stable and continuous source of income (Hollander, 1965; Sanderson & Uzumeri, 1995). For example, exploitative market learning in the context of product development is positively associated with product cost efficiency (Kim & Atuahene-Gima, 2010). Conversely, drastically changing technologies, designs, and mechanisms underlying current products is associated with increasing likelihood of organizational failure (Barnett & Carroll, 1995; Winter, Szulanski, Ringov, & Jensen, 2012).

Consequently, firms are not able to survive and prosper by focusing on either exploitative innovation or exploratory innovation alone, but need to balance them. In other words, a marginal increase in exploratory (or exploitative) innovation enables favorable firm performance to the extent that a corresponding increase in exploitative (or exploratory) innovation accompanies it. The balance is critical because it minimizes the possibility that one overwhelms, contradicts, and disturbs the other (Andriopoulos & Lewis, 2009; Boumgarden et al., 2012; O'Reilly & Tushman, 2008). As they mutually compensate for each other's deficiencies, neither should be a dominant mode of innovation. In other words, the negative externalities between exploratory and exploitative organizational design elements (Boumgarden et al., 2012) can be minimized by balancing them.

Accordingly, the mutually compensatory relationship between exploitative innovation and exploratory innovation underlies firms' higher adaptability because firms satisfy differential competitive requirements, including efficiency and flexibility, by simultaneously pursuing exploitative as well as exploratory innovation. This dimension of organizational ambidexterity can be captured by its balance dimension (Cao et al., 2009), which is characterized by a firm's equal emphasis on exploitation and exploration. In other words, the balance dimension of innovation ambidexterity enables firms to survive and prosper by ensuring current, as well as future viability (Levinthal & March, 1993).

Hypothesis 1: The balance dimension of innovation ambidexterity is positively associated with organizational performance.

2.3 Mutually enabling relationship between exploitative and exploratory innovation

Although, the balance, or relative magnitude of exploitative and exploratory innovation, is important, we also argue that absolute magnitude of both innovation is critical because exploratory innovation and exploitative innovation mutually enable each other, or the former directly seeds and primes the latter by preparing knowledge, designs, and mechanisms useful for the latter, and *vice versa*. We refer to such relationship as a mutually enabling relationship between exploitative innovation and exploratory innovation. The more exploratory innovation an organization pursues, the more they learn to uncover opportunities for exploitative innovation. Furthermore, the more exploitative innovation an organization pursues, the more they learn to weave opportunities for exploratory innovation. Therefore, the locus of complementarity is acts of exploration and exploitation *per se*, because exploration and exploitation directly enable each other.

As engineers work on exploratory innovation, they explore wide varieties of alternative technological knowledge, designs, and mechanisms, including those beyond their current areas of strength. An interesting consequence of their exploration is the generation of product refinement opportunities for subsequent exploitative innovation efforts. A typical example is product development activities targeted to define new design rules (Baldwin & Clark, 2000) or product platforms (Meyer, 1997; Muffatto & Roveda, 2000). Engineers explore wide varieties of design alternatives, so that they can identify "robust designs (Gardiner, 1984)" that they can fully exploit through later refinements. In other words, exploratory innovation seeds subsequent exploitative innovation.

In contrast, when engineers are involved in exploitative innovation, they focus on replicating and reusing existing technological knowledge, designs, or mechanisms across multiple new product innovation projects (Nooteboom, 2000). However, perfect replication is rare, because each project context calls for adjustments and modifications to the original technological knowledge, designs, or mechanisms (Feldman & Pentland, 2003; Winter & Szulanski, 2001; Winter et al., 2012; Zollo & Winter, 2002). These adjustments and modifications generate varieties of alternative ideas from which engineers build next rounds of exploratory innovation by exchanging and recombining these alternative ideas (Nooteboom, 2000; Zollo & Winter, 2002). Examples of this phenomena include wireless telephony (Levinthal, 1998), fiber optics (Cattani, 2006), and industrial equipment manufacturing (Salvador et al., 2014). Therefore, exploitative innovation primes subsequent exploratory innovation (Zollo & Winter, 2002).

The foregoing discussion indicates organizations that vigorously pursue both exploitative and exploratory innovation benefit from the mutually enabling relationship between exploitative and exploratory innovation. The mutually enabling relationship is distinct from the mutually compensatory relationship because the latter is characterized with the balance that minimizes the negative externalities between exploratory and exploitative organizational design elements (Boumgarden et al., 2012), while the former entails offsetting the negative externalities through exchanges of technological knowledge, designs, and mechanisms between exploratory innovation and exploitative innovation. More specifically, exploitative (or exploratory) innovation enables favorable firm performance to the extent that accompanying exploratory (or exploitative) innovation increases. In other words, the performance benefits of exploitative (or exploratory) innovation are multiplicative, because exploitation's (or exploration's) effect is multiplied by subsequent exploratory (or exploitative) innovation. This dimension of organizational ambidexterity can be captured by its combined dimension (Cao et al., 2009), which is a combined (or multiplied) magnitude of exploitation and exploration. Therefore, the combined dimension of innovation ambidexterity allows firms to try more opportunities for exploitative as well as exploratory innovation, thereby increasing the likelihood that they enjoy successful results (Klingebiel & Rammer, 2014). We expect such effective innovation positively influences firms' adaptability, and then contributes to higher firm performance (Clark & Fujimoto, 1991; Imai, Nonaka, & Takeuchi, 1985).

Hypothesis 2: The combined dimension of innovation ambidexterity is positively associated with organizational performance.

3. Methods

3.1 *Sample*

We tested the hypotheses with data from the pharmaceutical industry. We particularly leveraged data on new pharmaceutical products development in the Japanese market to operationalize our sample firms' degree of innovation ambidexterity. Because the Japanese market is the second largest country market for pharmaceutical products, most global pharmaceutical firms actively compete there. Furthermore, the data from the Japanese market for new pharmaceuticals development are appropriate for a number of reasons.

Firstly, upon the approval of all new ethical drugs, independent specialists, including physicians, scientists, payers, and pharmaceutical firms, determine whether each new pharmaceutical contains an NCE (new chemical entity) or not. This distinction is useful for our operationalization, because an NCE-based pharmaceutical product is traditionally thought to represent an exploratory innovation in the context of new pharmaceutical development, while a non-NCE-based pharmaceutical product is thought to represent an exploitative innovation (Bierly & Chakrabarti, 1996; Cardinal, 2001; Dunlap-Hinkler et al., 2010).[1] An NCE represents an entirely new chemical entity that did not exist as an ethical pharmaceutical drug before. Therefore, finding an NCE requires a search beyond known libraries of active ingredients, while a non-NCE reuses NCEs already approved for medical use. An example of a pharmaceutical drug based on a new chemical entity is Eli Lilly's Prozac, while its descendent, such as Sarafem is an example of a non-NCE-based pharmaceutical developed from the same chemical entity called fluoxetine. Initially, fluoxetine was successfully developed as an anti-depressant (Prozac), and later, Eli Lilly redeveloped it for a different indication of premenstrual dysphoric disorder (Sarafem) upon Prozac's patent expiration.

Secondly, rich data on sample firms' exploitative as well as exploratory innovation activities are available. Pharmaceutical firms are required to report on their clinical trial activities to the regulatory agency, which then discloses the information to the public. Investors also pressure listed pharmaceutical firms to disclose their pipeline (i.e., pharmaceutical candidates under development) information because successful new pharmaceutical developments substantially influence firms' financial performance. Therefore, we are able to compile a comprehensive data set on virtually all major pharmaceutical industry participants' new product innovation activities between 1991 and 2000.

A professional medical magazine, called *New Current*, publishes exhaustive lists of pharmaceuticals under development on a quarterly basis since 1990. The list shows each pharmaceutical firm's detailed pipeline information including, the name of pipelines, targeted therapeutic indications, stages of clinical trials, and whether each pipeline contains an NCE or not. With these data, we operationalized sample firms' longitudinal new product innovation activities by precisely quantifying their degree of exploitation and exploration.

Our database consists of global and Japanese pharmaceutical firms who gained new pharmaceutical approvals during January 2001 to December 2010 in the Japanese market. Firstly, we selected pharmaceutical firms that actively develop new pharmaceutical products by identifying 93 global as well as Japanese firms that gained new pharmaceutical approvals between January 2001 and December 2010 in the Japanese market. Then, we dropped nine firms from our sample, because they

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1 We operationalize exploratory innovation and exploitative innovation by considering whether NCEs are used or not, which has nothing to do with the degree of new product innovativeness or radicalness. Pharmaceutical firms sometimes explore an NCE to apply it to existing therapeutic mechanisms of action, realizing incremental efficacy improvements at best. For example, Bristol-Myers Squibb's Taxol (paclitaxel) and Sanofi-Aventis' Taxotere (docetaxel) are different chemical entities, but they share the same mechanisms of action, and they both are used for the treatment of breast, ovarian, and lung cancer. On the contrary, firms sometimes develop radical breakthrough pharmaceutical products by reusing existing chemical entities already developed as ethical pharmaceutical products. A good example is Pfizer's Viagra, which was initially developed for an indication of angina. Likewise, Sarafem, a descendent of Prozac, is the first ethical drug approved by FDA for the treatment of premenstrual dysphoric disorder.

were either acquired or dissolved. With this procedure, we expect to focus on pharmaceutical firms that show continuous commitment to new product development. Then, we set our observation period at 1991 to 2000, or 10 years preceding these approvals because pharmaceutical development takes roughly 10 years (Pisano & Rossi, 1994). On those firms, we constructed longitudinal panel data over 10 years (from 1991 to 2000) by collecting data on number of employees, R&D expenses, and pharmaceutical pipelines from 1991 to 2000. Due to the lack of available financial data, we excluded 34 private firms (most of them are small firms with less than two new pharmaceutical approvals from 2001 to 2010). Consequently, our final sample includes 461 firm-years on 50 firms. Combined sales of these 50 firms represent 72% of the total global pharmaceutical market as of 2010.

3.2 Variables and analysis

In order to test our hypothesis, we constructed measures of two distinct mechanisms underlying innovation ambidexterity and tested their associations with sample firms' revenue growth. The use of panel data helps us to control for potential sources of unobserved heterogeneity. We chose the random-effects GLS (generalized least squares) model, rather than the fixed-effects model due to two reasons. Firstly, because our dataset is a short panel (i.e., number of units exceeds observations per unit) and our independent variables change very gradually over time, or "sluggish", in comparison to our dependent variable, fixed-effects models may be plagued with the high variance problem, or unstable estimates that is overly sensitive to the random error in the dataset (Clark & Linzer, 2015). On the other hand, random-effects models provide more stable estimates for this type of dataset by partially pooling information across units (Gelman & Hill, 2007). Secondly, our models employ a time-invariant variable, while the fixed-effects model does not allow estimation of the coefficient for time-invariant regressors. For the same reason, the conventional approach to validate the choice between random-effects and fixed-effects, i.e., the Hausman test, is unavailable for our case because we cannot compare the between-estimator and the within-estimator.

Because panel data include multiple observations per sample firm, observations for the same firm are likely to be correlated. Such a serial correlation of errors within cross-section may deflate standard errors and inflate significance levels. Indeed, Wooldridge's test for serial correlations (Drukker, 2003; Wooldridge, 2002) rejected a null hypothesis of no serial correlation. Therefore, we calculated standard errors using the robust clustered estimator (Arellano, 1987; Huber, 1967; White, 1980) because it produces consistent standard errors (Froot, 1989; Williams, 2000). This estimation is also robust to heteroskedasticity, or another concern associated with panel data analysis (Cameron & Trivedi, 2009, p. 85). Below, we describe variables employed in our model.

Dependent variable

Our dependent variable is sample firms' total *revenue growth* rate over a three-year period. For example, *revenue growth* for the year 1991 ($Year_t$) is defined as a growth rate from 1991 to 1994. Prior works on organizational ambidexterity (Cao et al., 2009;

Derbyshire, 2014; He & Wong, 2004; Lubatkin et al., 2006) operationalize firm performance with *revenue growth*, and we follow them so that our results are easily comparable to them. In addition, we hypothesize ambidexterity benefits in terms of a firm's adaptation, and *revenue growth* best captures the effectiveness of the firm's adaptive performance, or the extent to which the firm successfully adjusts its products or services to the changing competitive landscape. Scholars measure performance benefits of ambidexterity over the timeframe of five years (Gibson & Birkinshaw, 2004), three years (He & Wong, 2004), two years (Jansen, Simsek, & Cao, 2012), and one year (Cao et al., 2009; Lubatkin et al., 2006), so we selected a three-year period as an average of the longest (i.e., five) and the shortest (i.e., one).

Although scholars often use such measures of profitability like return on assets (ROA) to operationalize firm performance, we feel profitability is not an appropriate measure for our empirical purpose because higher profitability (or higher cost efficiency) is generally associated with exploitation, rather than with organizational ambidexterity (March, 1991; Salvador et al., 2014). We did not choose patent measures because they only capture firms' inventive performance, which only remotely influences firms' adaptability.

Independent variable

Our independent variables are each sample firm's degree of innovation ambidexterity. Following Cao et al. (2009), we measured the degree of a balance dimension (H1) and a combined dimension (H2) of innovation ambidexterity as below.

We tested our first hypothesis by measuring the balance dimension of innovation ambidexterity ($ambidexterity_b$) with the absolute difference between a share of non-NCE pipelines (in total pipelines) and that of NCE pipelines (Cao et al., 2009). Smaller value of this measure indicates more balanced and thus higher innovation ambidexterity (therefore, we expect a negative coefficient for this measure). For example, Takeda Pharmaceutical, one of the major Japanese pharmaceutical firms, had 37 pipelines in 1991, including 32 NCEs pipelines and five non-NCEs pipelines. Our measure of the balance dimension of ambidexterity is then 0.73 (32/37-5/37). It may be ideal to directly measure the extent to which existing knowledge is reused (or new knowledge is pursued) across every new product innovation project over time. Whereas such data might be obtainable on a small scale, our measure, although representing only limited aspect of new product innovation activities, allows us to capture innovation characteristics for virtually all major industry participants over an extended period of time.

Similarly, each sample firm's degree of combined dimension of innovation ambidexterity ($ambidexterity_c$) is operationalized by a count of non-NCE pipelines multiplied by that of NCE pipelines, divided by a count of total pipelines. Because our hypothesis is concerned about combined magnitude of exploitative and exploratory innovation, we followed prior works (Cao et al., 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004) to capture our sample firms' degree of emphasis on vigorously pursuing both exploitation and exploration by multiplying respective magnitude (or an absolute amount) of exploitative and exploratory initiatives. Then, we divided it by a count of total pipelines due to following two reasons. Firstly, our dependent variable is a size-adjusted measure, and we feel it consistent to eliminate influences of organizational size from our independent variable as well. Secondly, employing a size-adjusted measure also allows us to make sure that effects of the size of sample firms' product development portfolio does not confound our measurement of ambidexterity, and its effects on firm performance. For example, in the case of Takeda Pharmaceutical at 1991, our measure of the combined dimension of ambidexterity is 4.32 (32 * 5 / 37).

Control variables

In addition to the independent variables, we controlled for a variety of organizational and environmental factors in our models. Our first control variable is *R&D intensity*, which is a measure of the degree of sample firms' innovativeness. It is operationalized by a sample firm's research & development expenditure divided by its revenue at $Year_t$. We also included sample firm's total number of employees (divided by a thousand for rescaling) at $Year_t$ as a measure of sample firms' organizational *size*. In addition to effects of internally grown resources, we expect that this measure also captures effects of M&A activities. Because firms with thick accumulation of routines may grow slowly, sample firms' *age* at $Year_t$ was also included. It is operationalized by sample firms' age counted as a number of years since their foundation (divided by a thousand for rescaling). Because we employed this measure as an indication of routines accumulation, we adjusted for the effects of mergers because mergers create a new set of routines while partially maintaining formerly distinct sets of merged partners' routines. More specifically, we averaged merged partners' ages and the age of a newly created organization.[2] For example, in the case of the merger between Astra AB and Zeneca Group plc that resulted in AstraZeneca plc, we averaged the ages of Astra AB, Zeneca Group plc, and AstraZeneca plc.

Our forth control variable is a measure of the extent to which sample firms are characterized with the *attainment discrepancy* (Cyert & March, 1963; Lant, 1992), or the discrepancy between targeted performance and achieved performance. The magnitude of attainment discrepancy may influence firms' revenue growth because firms' degree of risk preference varies depending on their attainment discrepancy (*ibid.*). We operationalized the extent the focal firm is characterized with the attainment discrepancy by dividing sample firms' revenue ($Year_t$) by that of prior year ($Year_{t-1}$), and then subtracting the overall pharmaceutical industry's growth rate from $Year_{t-1}$ to $Year_t$. Firms may also differ in terms of their *long-term orientation*, which may positively influence their revenue growth rate. Therefore, we included a share of pipelines at a phase 1 of clinical trial or before (over total pipelines) at $Year_t$ to control for this possibility.

It also may be important to control for the effects of time-invariant firm characteristics. Thus, we included a "*Japanese firm*" dummy variable for those firms head-

2 In the case of acquisitions, acquired firms' routines are quickly assimilated to those of acquirers. Therefore, we did not make such adjustments for acquires' ages unless acquirers substantially changed their way to develop new products, manage distribution, and interact with customers.

quartered in Japan. Because firms' technological scope may influence their growth potential, our model employed a degree of *technological scope* in sample firms' search behavior, operationalized by the number of the United States Patent and Trademark Office's 3-digits technological classes to which the sample firm filed patent applications during $Year_{t-4}$ and $Year_{t}$.

Lastly, we controlled for the effects of overall *industry growth* by including 3-year growth rate of the worldwide pharmaceutical market. A measure of the degree of *globalization* of competitive contexts, operationalized by the annual share of emerging markets (i.e., Latin America, Africa, Australia, and Asia excluding Japan) was also included.

4. Results

Table 1 shows descriptive statistics and a correlation matrix for all the variables employed in our models. Overall, our variables show considerable variability, and most correlations among them range from small to moderate (except for those between alternative independent variables). We also checked the VIF (variance inflation factors) for all variables and none of them exceeds 3.0, which indicates a very limited threat of multicollinearity because they are well below the rule of thumb threshold of 10.0 (Cohen, Cohen, West, & Aiken, 2003). Secondly, we checked the mean VIF for each model and none of them is considerably larger than 1.0, further alleviating our concern on multicollinearity (Chatterjee & Price, 1991). Finally, we don't observe dramatic changes in coefficients across models with and without our independent variables, so we conclude that the threat of multicollinearity is negligible (Neter, Kutner, Nachtsheim, & Wasserman, 1996).

Table 2 reports the results of our tests of hypotheses. Model 1 shows the results with the control variables. The independent variables (i.e., a measure of innovation ambidexterity) are added in model 2 and 3.

The results support our hypotheses on two mechanisms underlying innovation ambidexterity's performance benefits. As model 2 shows, the coefficient for $ambidexterity_b$ is negative and significant ($p < .01$), supporting the hypothesis 1. We also find a support for the hypothesis 2 in model 3 as a positive and significant coefficient for $ambidexterity_c$ ($p < .05$).

As for control variables, *size* and *Japanese firms* consistently show significant and negative associations with 3-year revenue growth, while we observe marginally significant positive coefficients for *long-term orientation*.

Table 1: Descriptive statistics and correlations

	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12
1. Revenue growth	4,67	7,12												
2. R&D intensity	9,81	4,80	,27 *											
3. Size	19,16	28,91	,14 *	,01										
4. Age	0,09	0,06	-,10 *	-,15 *	-,17 *									
5. Attainment discrepancy	-1,64	14,24	,15 *	,10 *	,12 *	-,08								
6. Long-term orientation	0,26	0,17	,05	-,07	,00	-,12 *	-,08							
7. Japanese firm	0,69	0,46	-,41 *	-,34 *	-,67 *	,17 *	-,22 *	,09						
8. Technological diversity	22,49	19,05	,11 *	-,21 *	,67 *	-,13 *	,06	,10 *	-,46 *					
9. Industry growth	7,20	3,86	-,03	,04	,00	-,02	,19 *	,07	,00	,01				
10. Globalization	16,17	2,97	,01	,07	,05	-,04	,06	,15 *	-,03	,09	,45 *			
11. Ambidexterity$_b$	0,47	0,29	-,08	,01	,06	-,14 *	-,08	,10 *	-,12 *	-,09	-,08	-,22 *		
12. Ambidexterity$_c$	3,14	2,27	,00	,07	-,03	,24 *	,05	-,02	,23 *	,07	,02	,13 *	-,60 *	
13. Exploitation	0,30	0,19	,06	-,09	,01	,10 *	,02	-,17 *	,01	,23 *	,05	,23 *	-,74 *	,70 *

Table 2: Results of the GLS random effects regression analysis for the effects of innovation ambidexterity on 3-year revenue growth

	Model 1			Model 2			Model 3		
R&D intensity	0,16		[0.12]	0,14		[0.12]	0,09		[0.12]
Size	-0,06	**	[0.02]	-0,05	*	[0.02]	-0,06	**	[0.02]
Age	-2,29		[9.68]	-5,00		[8.30]	-6,93		[8.84]
Attainment discrepancy	0,03	†	[0.02]	0,03		[0.02]	0,03		[0.02]
Long-term orientation	4,39		[2.70]	5,32	†	[2.82]	4,70	†	[2.67]
Japanese firm	-7,63	***	[1.62]	-8,20	***	[1.55]	-8,94	***	[1.71]
Technological diversity	0,01		[0.03]	0,00		[0.03]	0,00		[0.03]
Industry growth	-0,10		[0.09]	-0,09		[0.09]	-0,08		[0.09]
Globalization	0,00		[0.16]	-0,08		[0.16]	-0,04		[0.16]
$Ambidexterity_b$: H1				-3,74	**	[1.37]			
$Ambidexterity_c$: H2							0,44	*	[0.20]
Constant	8,90	*	[3.88]	12,93	**	[4.18]	10,52	*	[3.98]
N firm-years	461			461			461		
N Firms	50			50			50		
R-squared (within)	0,02			0,04			0,02		
R-squared (between)	0,44			0,47			0,47		
R-squared (overall)	0,22			0,24			0,24		
Chi-square	82,32			96,06			93,48		

a. Robust standard errors adjusted for clustering by firm are in parentheses. Two-tailed tests for all effects.

† $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5. Robustness tests

We conducted three post hoc analyses in order to further verify our research findings. Firstly, we follow prior works (Belderbos, Faems, Leten, & Looy, 2010; Uotila, Maula, Keil, & Zahra, 2009) to employ an alternative test of innovation ambidexterity's influence by examining whether we observe a curvilinear (inverted U-shape) relationship between firm performance and the relative share of exploitation (or exploration) in a firm's product development portfolio. We tested a model with linear and squared terms of a share of non-NCE pipelines ("*exploitation*") as independent variables. A curvilinear (inverted U-shape) relationship between *exploitation* and *revenue growth* lends support to our hypothesis. *Exploitation* is mean-centered so that we can properly observe the curvilinear (inverted U-shape) relationship (Aiken & West, 1991; Jaccard, Wan, & Turrisi, 1990). Model 4b in Table 3 shows that the coefficient for *exploitation* is positive and significant ($p< .05$), while that for the squared term is negative and significant ($p< .05$), indicating a curvilinear (inverted U-shape) relationship as expected. Further confirming the existence of a curvilinear relationship, we observe the peak of the inverted U-curve at a value of 22% for mean-centered "*exploitation*" (or 52% for a share of non-NCE pipelines), with 89% of the sample observations having smaller values than the peak value.

Table 3: Results of the GLS random effects regression analysis for the effects of innovation ambidexterity on 3-year revenue growth

	Model 1			Model 4a			Model 4b		
R&D intensity	0,16		[0.12]	0,16		[0.12]	0,11		[0.11]
Size	-0,06	**	[0.02]	-0,05	*	[0.02]	-0,05	*	[0.02]
Age	-2,29		[9.68]	-3,56		[8.84]	-5,33		[8.50]
Attainment discrepancy	0,03	†	[0.02]	0,03	†	[0.02]	0,02		[0.02]
Long-term orientation	4,39		[2.70]	5,53	*	[2.79]	5,22	†	[2.73]
Japanese firm	-7,63	***	[1.62]	-7,75	***	[1.69]	-8,40	***	[1.58]
Technological diversity	0,01		[0.03]	-0,01		[0.03]	-0,01		[0.03]
Industry growth	-0,10		[0.09]	-0,09		[0.09]	-0,08		[0.09]
Globalization	0,00		[0.16]	-0,07		[0.15]	-0,08		[0.16]
Exploitation				4,36	*	[2.09]	6,15	*	[2.45]
Exploitation (squared)							-14,31	*	[5.61]
Constant	8,90	*	[3.88]	10,21	**	[3.95]	12,07	**	[3.95]
N firm-years	461			461			461		
N Firms	50			50			50		
R-squared (within)	0,02			0,05			0,03		
R-squared (between)	0,44			0,44			0,48		
R-squared (overall)	0,22			0,23			0,25		
Chi-square	82,32			93,28			99,53		

a. Robust standard errors adjusted for clustering by firm are in parentheses. Two-tailed tests for all effects.

† $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Secondly, we tested the hypothesized effects on yet another alternative measure of forward-looking firm performance, i.e., Tobin's Q at Y_t. The results are fully consistent with our original findings, supporting hypothesis 1 ($p< .05$) and hypothesis 2 ($p< .05$).

Finally, we tested our hypotheses with the reduced data set that only includes pharmaceutical firms headquartered in Japan. The results shown are fully consistent with our original findings, lending further supports to hypothesis 1 ($p< .01$) and hypothesis 2 ($p< .05$). Overall, our post hoc analysis indicates that the previously reported findings are robust.

6. Discussion and conclusion

6.1 Theoretical implications

Although scholars have extensively discuss a complementary relationship between exploitation and exploration (Baker & Sinkula, 2007; Belderbos et al., 2010; Gupta et al., 2006; Katila & Ahuja, 2002; Kim & Atuahene-Gima, 2010, among others), it is rarely specified explicitly which aspects of exploitation and exploration are mutually complementary. One of the most widespread interpretations is that exploitation and exploration mutually compensate for deficiencies of each other, in that they contribute to firm performance in distinct, but mutually complementary ways. Put differently, exploitation's effects on firm performance complement exploration's effects, and *vice* *versa*. On the other hand, an alternative aspect of the complementary relationship, in which exploitation and exploration mutually enable each other, has been left unexplored. More precisely, little research has examined the relationship in which acts of exploitation complements acts of exploration by enabling the latter, and *vice versa*.

Our work is one of the first to build upon Cao et al. (2009)'s argument on two dimensions of ambidexterity and explicitly explain the differences between two types of complementary relationships in the context of new product innovation. Understanding such differences provides us a more detailed anatomy of the relationship between ambidexterity and organizational performance. More specifically, the mutually compensatory relationship and the mutually enabling relationship differ in terms of their locus of complementarity, their mechanisms of performance benefits, and their influences on the negative externality.

Furthermore, our finding also informs distinct directions for pursuing ambidexterity antecedents. The mutually compensatory relationship between exploitation and exploration suggests that ambidexterity is effectively achieved to the extent that exploitation and exploration are balanced. Therefore, ambidexterity is primarily an issue of resources allocation. Separating exploitative and exploratory organizational units should be an effective antecedent, because it enhances the mutually compensatory relationship by explicitly distinguishing resources allocated to both. On the other hand, the mutually enabling relationship indicates that learning shared by those in charge of exploitative innovation and exploratory innovation critically influences the extent to which an organization is ambidextrous. Put differently, ambidexterity is an issue of organizational processes. Manipulating behavioral patterns or organizational culture would be more relevant and effective intervention to increase the degree of ambidexterity. As such, our in-depth examination of the ambidexterity-performance relationship informs a future research on ambidexterity antecedents.

6.2 Practical implications

As for practical implications, it is important to note that our panel data analysis approach complement the cross-sectional perspective of the prior work. Given the possibility that firms are not necessarily free to choose their degree of ambidexterity, cross section analysis may over-estimate performance influences of ambidexterity, while panel data analysis provides more realistic implications by taking into account effects of temporal changes in each sample firm's degree of ambidexterity. Practitioners may also find that our findings provide more reliable inferences because our study examines longitudinal dynamics of firms' degree of ambidexterity, which is also called for by Raisch et al. (2009).

By replicating Cao et al. (2009)'s findings in a quite distinct empirical contexts, our work also reinforces the practical importance that those practitioners who aspire to fully benefit from their firms' ambidexterity should pay close attention to both the balance and combined dimensions of ambidexterity. In particular, our findings on the balance dimension and the combined dimension of innovation ambidexterity indicate how firms should correct imbalance between exploitative innovation and exploratory innovation. Firms gain more from innovation ambidexterity by vigorously pursuing both exploitative innovation and exploratory innovation, than by just allocating equal emphasis on them. Therefore, when exploitative innovation outweighs exploratory innovation, managers should correct the imbalance by increasing the latter, rather than decreasing the former. This may call for a substantial departure from current managerial decision-making behaviors, because difficulties associated with gaining additional resources generally drive managers' decision toward balancing through reduced (rather than increased) combined magnitude.

6.3 Limitations and future research

We conclude this manuscript by discussing our findings' limitations and implications for future research. First, we were not able to take into account our sample firms' external innovation activities. Extending the ambidexterity hypothesis from the level of each organization to the level of allied organizations requires a completely new set of hypothesis developments (including theories on network ties, knowledge absorption, and firm boundaries management, among others) and appropriate empirical operationalization, which is beyond the scope of this manuscript. Given increasingly important roles played by equity arrangements between pharmaceutical companies and biotech firms, including such external innovation activities as an indispensable part of firms' innovation performance is an important future research agenda.

Secondly, we were not able to uncover how two underlying mechanisms of innovation ambidexterity interact with firms' choice of organizational structure, process design, or product architecture. Because these are important determinants of product development performance (Baldwin & Clark, 2000; Clark & Fujimoto, 1991), we have much to learn on what types of organizational structure, process design, and product architecture are appropriate for innovation ambidexterity. Finally, identifying antecedents of two mechanisms underlying innovation ambidexterity (Gibson & Birkinshaw, 2004, among others) is a related, but distinct research direction for the future. Deeper understanding of underlying mechanisms will help us to explain more precisely which antecedents enable alternative dimensions of innovation ambidexterity. We hope our manuscript stimulates research interests in this promising field of inquiry.

6.4 Conclusion

We hypothesized and empirically showed that firms gain from innovation ambidexterity through two distinct mechanisms. Our findings on the balance dimension of innovation ambidexterity (H1) show that exploitative innovation and exploratory innovation compensate for deficiencies of each other, and enable firms to effectively adapt their products to the changing competitive requirements. We also show that the combined dimension of innovation ambidexterity (H2) contributes to firms' adaptability via higher likelihood of successful innovation enabled by a mutually enabling relationship between exploitative innovation and exploratory innovation.

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