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How do internal capabilities and external partnerships affect innovativeness?

Yu-Shan Su · Eric W. K. Tsang · Mike W. Peng

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Abstract How do a firm's internal capabilities and external partnerships contribute to its product and process innovativeness? How do their impacts differ? Based on the theoretical framework of exploitation and exploration, we develop an integrative model linking the impact of both internal capabilities and external partnerships on product and process innovativeness. Survey responses from Taiwanese biotechnology firms indicate that research and development (R&D), marketing, and manufacturing capabilities have different effects on product and process innovativeness. Of the four types of external partnerships, only partnerships with universities and research institutes seem to add value, whereas partnerships with suppliers, customers, and competitors do not contribute to innovativeness. Moreover, marketing capability and customer partnerships have a positive interaction effect on product innovativeness, while manufacturing capability and supplier partnerships have a positive interaction effect on process innovativeness.

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Y.-S. Su (✉)
Department of International Business, Chang Jung Christian University, Tainan 711, Taiwan
e-mail: belle@mail.cjcu.edu.tw

E. W. K. Tsang · M. W. Peng
School of Management, University of Texas at Dallas,
P.O. Box 830688, SM 43, Richardson, TX 75083-0688, USA

E. W. K. Tsang
e-mail: ewktsang@utdallas.edu

M. W. Peng
e-mail: apjmpeng@gmail.com

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How do firms innovate? There are two dominant approaches to innovation research. One views a firm's internal capabilities as the primary drivers of innovation (Dosi, 1982), and the other argues that innovation is driven by a firm's external partnerships (von Hippel, 1988). Although each approach highlights a key aspect of innovation, internal capabilities and external partnerships are not necessarily mutually exclusive. Greater insight may be derived from the *joint* consideration of both approaches. Recently, an "open innovation" model argues that valuable ideas can come from inside or outside the firm and can go to market from inside or outside the firm as well (Chesbrough, 2003; Laursen & Salter, 2006; Lu, Tsang, & Peng, 2008). However, the model has rarely been empirically examined. Two key questions remain to be addressed: How do a firm's internal capabilities and external partnerships contribute to its product and process innovativeness? How do their impacts differ?

This article addresses these two key questions. Drawing on the theoretical framework of exploitation and exploration (March, 1991), we propose an integrative model arguing that both internal capabilities and external partnerships affect a firm's innovativeness, which refers to the propensity of a firm to innovate (Ettlie, Bridges, & O'Keefe, 1984; Van de Ven, 1986). We test the model with survey data collected from the biotechnology industry, which is broadly defined as an industry that manipulates living organisms (or parts thereof) for the production of goods and services. Today, the biotechnology industry is commercialized in various product markets, such as pharmaceuticals, food, agriculture, chemicals, as well as environmental and pollution controls. The industry, which is primarily innovation driven, offers an attractive context for our study. There have been a number of studies based on the industry mostly in Western countries (Junkunc, 2007; Phene, Fladmoe-Lindquist, & Marsh, 2006; Powell, Koput, & Smith-Doerr, 1996; Rothaermel & Deeds, 2004, 2006; Shan, Walker, & Kogut, 1994). Unlike previous work, our study is conducted in the context of the Taiwanese biotechnology industry, which started late but is now growing fast in this newly industrialized economy. Overall, this article contributes to the literature not only by developing and testing an integrative framework linking both internal capabilities and external partnerships to innovation, but also by shedding light on a novel context not investigated by previous research.

Theoretical background

Managing innovation is about managing consistency, control, and variability (Rogers, 1995; Tushman, Anderson, & O'Reilly, 1997). One view suggests that a firm's knowledge to innovate is usually drawn from exploitation of internal sources, as technological innovations often follow a trajectory constrained by a firm's existing capabilities (Dosi, 1982; Junkunc, 2007; Katila & Ahuja, 2002; Winter, 1984). In contrast, another view argues that knowledge to innovate may stem from

external sources—at the interface between firms, universities, research laboratories, suppliers, and customers (Baum & Silverman, 2004; Rothermael & Deeds, 2006; von Hippel, 1988). This latter view suggests that the external partnerships formed by a firm offer an opportunity for exploration of knowledge, and thus play an important role in shaping its innovation performance (Baum, Calabrese, & Silverman, 2000; Powell et al., 1996; Shan et al., 1994).

Studies rarely examine both sources of innovation. For example, Junkunc (2007) indicates the important impact of internal specialized knowledge on radical innovation in the biotechnology industry without taking into account knowledge from external sources of the firm. On the other hand, Baum et al. (2000), Baum and Silverman (2004), and Rothermael and Deeds (2006) discover interesting alliance effects on innovation performance in the biotechnology industry, but do not investigate how internal capabilities (other than the alliance management capability) can also contribute to innovation performance.

Studies that examine the effects of either internal capabilities or external partnerships alone are not likely to provide a comprehensive picture of what determines innovation performance. In fact, their results may suffer from omitted variable biases because other studies have found that both internal capabilities and external partnerships impact performance. Lee, Lee, and Pennings's (2001) study, for example, suggests that internal capabilities and social capital interactively influence Korean technological start-up firms' performance. Similarly, Zaheer and Bell's (2005) study of Canadian mutual fund companies shows that a firm's innovative capabilities and its network structure enhance firm performance. Specifically on the topic of innovation performance, the results of Galoghirou, Kastelli, and Tsakanikas' (2004) survey of seven European countries indicate that both internal capabilities and openness towards external knowledge sharing are important drivers behind innovation performance.

March's (1991) framework of exploitation versus exploration throws light on the complementary nature of internal capabilities and external partnerships. March argues that the distinction between exploitation of existing capabilities and exploration of new possibilities captures a number of fundamental differences in firm behavior and performance. In particular, maintaining an appropriate balance between exploitation and exploration is crucial (Gupta, Smith, & Shalley, 2006; O'Reilly & Tushman, 2004). Similarly, Stieglitz and Heine (2007) argue that complementarity is an important concept in a strategic theory of the firm and a critical task of managers is to coordinate complementary assets and activities. In the context of innovation, integration of knowledge plays a crucial role in a firm's ability to generate innovations. Schumpeter (1934) maintains that recombinations of existing physical and conceptual materials lead to innovation. Combinative capability (Kogut & Zander, 1992) and architectural competence (Henderson & Cockburn, 1994) enable integration of external knowledge with internal capabilities to innovate. Following this line of argument, we argue that *both* exploitation of internal capabilities and exploration of external partnerships would contribute to a firm's innovativeness. Moreover, internal capabilities serve as a foundation for identifying and exploring external opportunities from partnerships, which in turn lead to the exploitation of internal capabilities.

While innovations can be classified in different ways, the distinction between product and process innovations is probably the most popular classification adopted by previous studies (Adner & Levinthal, 2001; Damanpour & Gopalakrishnan, 2001; Lim, Garnsey, & Gregory, 2006; Utterback & Abernathy, 1975). *Product innovation* is defined as new products or services introduced to meet an external market need, and *process innovation* as new elements introduced into operations (Ettlie & Reza, 1992). Product innovations have a market focus and are primarily customer driven, while process innovations have an internal focus and are primarily efficiency driven (Gopalakrishnan, Bierly, & Kessler, 1999). Moreover, Weiss (2003) argues that firms favor product innovation when competition is severe, and that they favor process innovation when competition is less severe.

Previous studies have typically examined these innovations separately, focusing only on product innovation (Danneels, 2002) or process innovation (Reichstein & Salter, 2006). Such separation partly contributes to the view of many innovation researchers that understanding innovative behavior in organizations has remained relatively underdeveloped, inconsistent, and inconclusive (Fiol, 1996; Gopalakrishnan & Damanpour, 1997). Although some approach the dynamics of both product and process innovations from the perspective of industry life cycle at the industry level (Adner & Levinthal, 2001; Lim et al., 2006; Utterback & Abernathy, 1975), the pattern of such innovations *at the firm level* remains unclear. Damanpour and Gopalakrishnan's (2001) study is one of the few that discuss both innovation types at the firm level. However, their focus is about the adoption of innovation rather than factors affecting innovation performance. To start filling this gap and to provide a more comprehensive understanding of innovation, we develop an integrative framework that links *both* types of innovativeness, and argue that internal capabilities and external partnerships have different effects on each type.

Hypotheses

Internal capabilities and innovativeness

Dutta, Narasimhan, and Rajiv (2005) conceptualize capabilities as the efficiency with which a firm transforms available inputs into outputs. A firm's innovativeness tends to be constrained by its existing capabilities (Dosi, 1982; Teece, 1986). There are three broad types of internal capabilities: (1) R&D, (2) marketing, and (3) manufacturing. As each type of capability has its unique features, we argue that these three types of capabilities have different impacts on product and process innovativeness.

A firm's R&D capability reflects its ability to generate new scientific discoveries and technological breakthroughs. Danneels (2002) considers R&D capability as a second-order technological competence and finds in his study of five high-tech firms that this capability contributes to product innovation. R&D capability directs and supports new product and process development (Dosi, 1982; Helfat, 1994). Firms are likely to search for new product and process ideas in areas related to prior

accumulation of R&D capability. In brief, R&D capability is essential for both product and process innovations. Hence:

Hypothesis 1a R&D capability has positive effects on both product and process innovativeness.

Product and process innovations need to be successfully commercialized before a firm can reap the rewards of its R&D capability (Cohen & Levinthal, 1990; Teece, 1986). A high level of R&D capability does not guarantee commercially successful appropriation. A firm may also require complementary assets or capabilities to successfully commercialize innovations (Teece, 1986). These capabilities include marketing and manufacturing skills.

Marketing capability is defined here as integrative processes designed to apply the collective knowledge and skills to add value in the marketing domain (Day, 1994). It creates a knowledge base about customer needs and market trends, and sharpens the firm's ability to add new value. The ability to pioneer markets is especially crucial in markets with a short product life cycle, such as biotechnology (Hatch & Marcher, 2004). Since product innovations have a market focus (Utterback & Abernathy, 1975), marketing capability may enable firms to take advantage of market opportunities (Atuahene-Gima & Evangelista, 2000). Thus, a strong marketing capability may facilitate *product* innovations.

In contrast, process innovations have an internal focus and are primarily efficiency driven (Tornatzky & Fleisoher, 1990; Utterback & Abernathy, 1975). Manufacturing capability may have a stronger impact on *process* innovations. Manufacturing capability is a complex capability integrating a large number of specific skills relating to components manufacturing, supply chain management, production scheduling, assembly processes, quality control procedures, and inventory control mechanism (Grant, 2002). Manufacturing capability is necessary for specifying the procedures and equipment for scale-up and process development, and thus would facilitate process innovations. Overall, marketing and manufacturing capabilities may be important for product and process innovativeness, respectively. Therefore:

Hypothesis 1b Marketing capability has a greater effect than manufacturing capability on product innovativeness.

Hypothesis 1c Manufacturing capability has a greater effect than marketing capability on process innovativeness.

External partnerships and innovativeness

When endeavoring to innovate, firms face an important strategic consideration: Exploiting existing competencies may provide short-term success, but can become a hindrance to the firm's long-term viability by stifling the exploration of new competencies (Leonard-Barton, 1992; Levinthal & March, 1993). Many firms appear to exploit and explore simultaneously (Dougherty, 1992; O'Reilly & Tushman, 2004; Peng, 2001). Millson, Raj, and Wilemon (1996) argue that to overcome the limitations of internal resources, firms should make more use of

formal or informal partnering arrangements with others to accomplish their innovative goals. Strategic alliances provide a platform for organizational learning, giving partner firms access to new knowledge. Through shared decision making, execution of alliance tasks, mutual interdependence and problem solving, firms can learn with and from their partners. In fact, managing an alliance itself is a learning process (Inkpen & Tsang, 2005; Kale & Singh, 2007).

Research has shown a clear relationship between interorganizational collaborations and innovation outputs in biotechnology firms (Baum et al., 2000; Shan et al., 1994; Walker, Kogut, & Shan, 1997). Moreover, interorganizational collaborations tied to diverse types of partners may lead to even higher innovation performance in the biotechnology industry (Owen-Smith & Powell, 2004; Powell et al., 1996). Following Germunden, Ritter, and Heydebreck (1996), we categorize a biotechnology firm's external partnerships into four groups, namely, partnerships with (1) upstream suppliers, (2) downstream customers, (3) horizontal competitors, and (4) universities and research institutes (URIs). The first two types of partnerships may involve outsourcing activities. Overall, we hypothesize:

Hypothesis 2a External partnerships with suppliers, customers, competitors, and URIs have positive effects on both product and process innovativeness.

Among the four types of partnerships, not all may be of equal value to biotechnology firms. We argue that partnerships with URIs would be the most critical for three reasons. First, public sector research is widely regarded as making a significant contribution to the growth of high-tech industries by supplying basic scientific knowledge that the profit-oriented, private sector has few incentives to produce. For example, biotechnology firms traditionally have close collaborative relationships with URIs, by transforming the basic scientific knowledge discovered by URIs into viable products (Rothermal & Deeds, 2006). The large number of citations to scientific journals included in the patents of biotechnology firms indicate their heavy dependence on basic science (McMillan, Narin, & Deeds, 2000). Cockburn and Henderson's (1998) interviews with academics and experts in the U.S. pharmaceutical industry also find that it is critically important for researchers in private firms to keep abreast of the results of public sector research. More important, in order to access these results, it is crucial that these researchers be active collaborators with their public sector counterparts. In brief, partnerships with URIs may provide a source of basic scientific knowledge that is critical for firm innovation.

Second, partnerships with URIs are fundamentally different from partnerships with the other three types of for-profit partners (Lane & Lubatkin, 1998). There may be more conflicts of interest in the partnerships with the three types of for-profit partners. For example, firms tend to lower the price they pay their suppliers and raise the price they charge their customers. On the other hand, conflicts of interest may be less prominent in partnerships with URIs, whose faculty, researchers, and students may have founded some biotechnology firms in the first place. Thus, there is a higher chance of establishing interpartner trust with URIs. Trust not only reduces transaction costs (Dyer & Chu, 2003), but also facilitates knowledge transfer and sharing (Inkpen & Tsang, 2005).

Finally, there is strong empirical evidence that URI collaborations would benefit firm innovation in the biotechnology industry. For example, Zucker, Darby and

Brewer's (1998) study of the U.S. biotechnology industry indicates that the rates of firm founding and rates of new product introduction are associated with connections to "star" university scientists. Studies have also found that interorganizational collaborations' contribution to innovation performance is particularly salient among firms with ties to universities (George, Zahra, & Wood, 2002; Owen-Smith & Powell, 2004). Thus,

Hypothesis 2b Partnerships with URIs have the greatest effect among the four types of partnerships on both product and process innovativeness.

Interaction of internal capabilities and external partnerships

The above hypotheses concern the separate effects of internal capabilities and external partnerships on innovativeness. Some scholars maintain that the effects of internal capabilities and external partnerships often interact with one another. For instance, Park, Chen, and Gallagher's (2002) study of the U.S. semiconductor industry suggests that firms' use of strategic alliances as a way to deal with market uncertainties is contingent upon internal resource conditions. Lavie and Rosenkopf (2006) argue that organizational inertia fosters the formation of exploitation alliances while absorptive capacity encourages the formation of exploration alliances.

Along a similar vein, recent research in strategy examines the issue of how interorganizational partnerships affect firms' ability to acquire resources and capabilities necessary for profitability and growth (e.g., Dyer & Hatch, 2006; Kale, Singh, & Perlmutter, 2000; Stuart, Hoang, & Hybels, 1999). Firms entering into strategic alliances may be motivated by exploitation and/or exploration reasons (Koza & Lewin, 1998, 2000; Rothaermel, 2001). In the early stage of a partnership, firms engage mostly in exploratory activities for discovering something new, which may lead to the codification of discovery through patenting. Following successful exploration, they turn to the commercialization of the new knowledge, which often requires exploiting existing complementary capabilities, such as manufacturing, marketing, and distribution (Rosenkopf & Nerkar, 2006; Rothaermel & Deeds, 2004). In other words, the internal capabilities of a firm provide a foundation for identifying and exploring external opportunities from its partnerships with other firms, which in turn lead to the further exploitation of its internal capabilities. We argue in this section that, owing to the complementary nature of the internal and external sources of innovativeness, certain elements of each source will interactively affect innovativeness.

Since product innovations have a market focus (Utterback & Abernathy, 1975), marketing capability may enable a new product development team to take account of market opportunities and threats and to enhance its understanding of new product commercialization strategy (Atuahene-Gima & Evangelista, 2000). Moreover, Christensen and Bower (1996) argue that the impetus of a firm's most powerful customers can capably articulate a need for product innovations. Customers are often a key source of new product ideas, but their role in process innovations remains unclear (von Hippel, 1988). Customer partnerships involve such market-related resources as knowledge of customer needs, preferences, purchasing procedures, distribution and sales access to customers, customer goodwill as reflected in the

reputation of the firm and its brands, and communication channels for information exchange during development and commercialization of the product (Danneels, 2002). It is likely that well developed customer partnerships may facilitate the exploitation of marketing capability and lead to product innovations that cater to meeting new customer needs. Thus, we propose such a synergy effect in the following hypothesis:

Hypothesis 3a Marketing capability and customer partnerships have a positive interaction effect on product innovativeness.

While product innovations are closely related to marketing capability, process innovations involve manufacturing capability as process innovations often refer to manufacturing that progresses from heavy reliance on skilled labor and general-purpose equipment to specialized equipment tended by low-skilled labor (Utterback, 1994). Suppliers are an important source of ideas for improving manufacturing and thus play a key role in process innovations. Rouvinen's (2002) study of Finnish manufacturing firms shows that process innovations are likely to draw on knowledge from upstream supplier partnerships. von Hippel (1988) argues that firms often need to work closely with their suppliers in order to understand and utilize the full potential of new technology and materials. It is crucial that firms are able to incorporate innovations of their suppliers into their manufacturing processes. Conversely, as Cockburn and Henderson (1998) argue, firms' own manufacturing capability affects their ability to absorb new knowledge from their suppliers. Such interactive dynamics suggest that integrating manufacturing capability with supplier partnerships should enhance process innovativeness and thus we propose:

Hypothesis 3b Manufacturing capability and supplier partnerships have a positive interaction effect on process innovativeness.

Finally, we examine the interactive dynamics between R&D capability and URI partnerships. To start with, McMillan et al. (2000) argue that biotechnology companies depend on public science as a source of new knowledge much more heavily than other industries. A major goal of alliances with universities and other research institutions is to embody leading-edge scientific discoveries into the biotechnology firm's products or processes (Rothermael & Deeds, 2006). Moreover, linkages with a university can supplement and expand a biotechnology firm's absorptive capacity through learning, lower the firm's R&D costs, and overcome some of its internal weaknesses in R&D (George et al., 2002). Similarly, in their study of research in drug discovery, Cockburn and Henderson (1998) argue that on the one hand, it is critical to conduct leading edge research inside a pharmaceutical firm (i.e., to build up its absorptive capacity) in order to be able to take advantage of public sector research results. On the other hand, collaborating with public sector scientists would raise the firm's own R&D capability. Following the argument of Hypothesis 1a that R&D capability is essential for both product and process innovativeness, we propose below that the synergy effect of R&D capability and URI partnerships would influence the two types of innovativeness:

Hypothesis 3c R&D capability and URI partnerships have a positive interaction effect on both product and process innovativeness.

Methods

Industry context

The Taiwanese biotechnology industry has a history that dates back to 1982 when the Taiwanese government launched the "Science and Technology Development Plan." This plan specified biotechnology as one of the eight key technologies to be developed for the economic growth of the country. Since then, the Taiwanese government has consistently supported the industry by setting up facilities and providing resources. Currently, biotechnology is designated as a "Twin Start Industry" and receives priority status for development in Taiwan. Within this short span of time, the Taiwanese biotechnology industry has evolved to range from biopharmaceuticals and agribiotech to biotechnology services. The 2005 Frost and Sullivan Consulting report indicates that Taiwan has a solid industrial development organizational structure and abundant investment resources for biotechnology.

According to Frost and Sullivan (2005), the Taiwanese biotechnology industry is thriving with approximately 200 companies and total revenues of US$947 million in 2003—the year of our survey. Although Taiwan occupies a relatively minor position in the global biotechnology value chain, Taiwanese biotechnology firms have leveraged their technical advantage, such as expertise in precision engineering and chip-making, to excel in certain areas such as diagnostic kits and biochips. Entrepreneurs and firms in Taiwan are enthusiastic about gaining biotechnology knowledge and pool their resources to spur the growth of this industry. The most promising biotechnology sectors in Taiwan are pharmaceuticals, biotechnology services, health food, herbal medicine, and agriculture. The R&D capabilities of Taiwanese biotechnology industry are significant regionally, but remain relatively weak globally. There is a shortage of highly trained personnel, and thus external partnerships have become imperative. As Bartholomew (1997) argues, country-specific institutional factors give rise to cross-national differences in innovation patterns. It would be interesting to study whether and how far the results of previous biotechnology studies in Western countries can be generalized to Taiwan, whose biotechnology firms, to the best of our knowledge, have not been studied before.

Sample and data collection

We conducted a survey in 2003 on firms listed in the *2002 Biotechnology Industry Annual Report of Industry and Technology Intelligence Services*, which included most of the biotechnology firms in Taiwan. We mailed questionnaires to the top managers of *all* 187 firms listed in the *Report*. We also mailed questionnaires to the 21 firms on the list provided by the Biotechnology Center of National Taiwan University. Thirteen of these firms were also listed in the *Report*. Follow-up letters, emails, and phone calls were made after two weeks. We also called the respondents if there were any missing data in their returned questionnaires. For the 208 questionnaires mailed out, a total of 95 responses (45.67%) were received and 11 of them were incomplete. The remaining 84 valid and complete responses, representing an effective response rate of 40.38%, were used for our analysis. The 84 respondents came from 79 firms, with five firms having two respondents. These five firms were

among the 13 to which we mailed two questionnaires. The respondent positions included 19 chief executive officers (CEOs), 10 vice presidents, and 55 managers (six of whom were executive assistants of CEOs).

Although each of the 84 returned questionnaires was answered by one respondent, the five pairs of responses from the same firms indicate that single respondent bias should not be a serious concern. We analyzed the correlation between the responses of each of the five pairs for the variables included in our study, and obtained five high correlation coefficients of 0.99, 0.85, 0.67, 0.55, and 0.45. For each pair, we averaged the responses for our regression analysis. That is, our dataset consisted of 79 observations, five of which were averages.[1]

Based on the literature and discussions with industry experts, we constructed the questionnaire items, which are listed in Appendix 1. We pilot tested a draft of the questionnaire with three CEOs from the biotechnology industry, and revised the draft based on their feedback. All items listed Appendix 1, except firm age and size, were based on seven-point Likert scales, ranging from (1) "strongly disagree" to (7) "strongly agree."

Operationalization of key variables

The dependent variable, innovativeness, refers to a firm's tendency to engage in and support new ideas, novelty, and experimentation that may result in new products, services, or processes (Lumpkin & Dess, 1996). Following Utterback and Abernathy (1975), we divided innovativeness into product and process innovativeness, and measured each by five items.

There were two sets of independent variables, namely, internal capabilities and external partnerships. We categorized capabilities into the functional areas of R&D, marketing, and manufacturing, and measured each by four items. Exploratory factor analysis, as shown in Appendix 2, supported this classification. External partnerships refer to the extent to which firms interact with partners. Exploratory factor analysis, as shown in Appendix 2, supported our categories of partnerships with suppliers, customers, competitors, and URIs.

We included several control variables, including firm age, firm size, financial variables, market turbulence, technology turbulence, and sub-industry types. First, we measured firm age by the number of years since founding, with the years categorized into seven intervals. Second, we measured firm size as the number of employees, again with seven intervals. Third, since financial performance may correlate with innovation performance, we included three financial variables—sales growth, net profit margin, and market share. Fourth, we controlled for market

[1] In 2007, we mailed the same questionnaires to the 74 firms that provided one response to our 2003 survey, and received 15 returned questionnaires. The respondents included three CEOs and 12 managers. We analyzed the correlation between the 15 pairs of 2003 and 2007 responses, and found that eight of the correlation coefficients were above 0.6 and only two were slightly negative (-0.10 and -0.16). Again, this suggests that the responses of the 2003 survey were rather reliable. We averaged the responses for each of the 15 pairs and compiled a new dataset by substituting these averages for the corresponding observations collected in the 2003 survey. That is, the dataset consisted of 79 observations, 20 of which were averages. We re-ran our regression analysis with this new dataset and found that the results were qualitatively similar to those reported in the next section.

turbulence and technology turbulence, each with four items. Finally, we grouped respondents into nine sub-industry categories: (1) biopharmaceuticals, (2) pharmaceuticals, (3) diagnostic agents, (4) biomedical materials, (5) Chinese medicine, (6) dietary supplements, (7) agriculture, (8) biotech services, and (9) others. We therefore created eight sub-industry dummies.

Analytic procedure

We conducted Harman's one factor test for identifying common method bias by entering the entire dependent and independent variables into a factor analysis. A basic assumption of this technique is that if a substantial amount of common method bias is present, either (1) a single factor will emerge from the factor analysis or (2) one general factor will account for the majority of the covariance among the measures (Podsakoff et al., 2003; Podsakoff & Organ, 1986). The first unrotated factor accounted for only 30.86% of the variance while all the nine factors accounted for 78.92%. This indicates that common method variance was not a serious problem in our study. The risk of common method variance was also reduced by the fact that, as mentioned, five observations were averages, each of which was based on two responses. Moreover, we collected data with numerical values, such as the number of new product introductions and sales growth in the past three years. Our results showed that product innovativeness had a positive, significant correlation with the number of new product introductions in the past 3 years (n=52), and both product and process innovativeness had positive, significant correlations with sales growth in the past 3 years (n=43). Thus, these additional data further validated the integrity of the data in our dataset.

Prior to creating the interaction terms, we standardized the variables to improve their interpretability and to reduce the threat of multicollinearity (Aiken & West, 1991). In this approach, the main effect terms used to construct the interaction terms are centered by subtracting the mean of each variable from observed values. This results in interaction terms having relatively low correlations with the related main effect terms. Moreover, we computed variance inflation factors (VIFs) for checking multicollinearity. The VIFs of all independent and dependent variables were less than 4, significantly lower than the typical cut-off value of 10. Therefore, there was little multicollinearity in our models.

Results

Table 1 presents the descriptive statistics. Table 2 lists the results of ordinary-least-square regression analyses of the main effects and the interaction effects, with Models 1 and 5 including only the control variables.

Since the coefficients of R&D capability in Models 2 and 6 are significant and positive, Hypothesis 1a is supported. Model 2 indicates that marketing capability has a significantly greater effect than manufacturing capability on product innovativeness, thus supporting Hypothesis 1b. Conversely, Model 6 shows that manufacturing capability has a significantly greater effect than marketing capability on process innovativeness, thus supporting Hypothesis 1c. Among the four types of partner-

Table 1 Means, standard deviations, and correlations.

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Product innovation	5.53	0.79															
2. Process innovation	5.09	1.05	0.47**														
3. R&D capability	5.46	0.96	0.55**	0.59**													
4. Marketing capability	4.87	1.37	0.62**	0.46**	0.54**												
5. Manufacturing capability	4.72	1.18	0.32**	0.58**	0.51**	0.45**											
6. Supplier partnership	4.49	1.24	0.40**	0.29**	0.34**	0.41**	0.29*										
7. Customer partnership	5.17	1.14	0.33**	0.30**	0.37**	0.40**	0.31**	0.35**									
8. Competitor partnership	3.05	1.36	0.18	0.20	0.25*	0.15	0.14	0.43**	0.29**								
9. URI partnership	5.39	1.15	0.27*	0.35**	0.23*	0.03	0.14	0.21	0.20	0.14							
10. Firm age	4.06	2.06	0.06	−0.18	−0.17	0.17	−0.11	−0.14	−0.06	−0.37**	−0.20						
11. Firm size	2.80	1.52	0.17	0.11	0.04	0.20	−0.10	−0.18	−0.12	−0.26*	0.01	0.56**					
12. Sales growth	3.82	1.53	0.48**	0.32**	0.26*	0.42**	0.30**	0.23*	0.16	0.07	0.14	0.15	0.24*				
13. Net profit margin	3.62	1.46	0.41**	0.38**	0.31**	0.42**	0.37**	0.25*	0.24*	0.13	0.09	0.17	0.16	0.68**			
14. Market share	3.70	1.45	0.42**	0.32**	0.28*	0.42**	0.28*	0.22	0.11	0.10	0.17	0.08	0.20	0.73**	0.63**		
15. Market turbulence	3.01	1.20	−0.22*	−0.22	−0.30**	−0.23*	−0.31**	−0.13	−0.13	−0.10	−0.08	0.08	−0.08	−0.14	−0.29**	−0.23*	
16. Technology turbulence	3.19	1.19	0.05	−0.12	−0.16	0.01	−0.12	0.10	−0.09	−0.12	−0.24*	0.23*	0.05	0.05	0.00	−0.11	0.37**

Two-tailed test. *$p<0.05$; **$p<0.01$. $N=79$.

Table 2 Results of regression analysis.

Variable	Product Innovativeness				Process Innovativeness			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
R&D capability		0.301**	0.324**	0.291*		0.261*	0.265*	0.258*
Marketing capability		0.294*	0.402**	0.313*		0.210	0.259†	0.216
Manufacturing capability		−0.093	−0.154	−0.093		0.327**	0.278*	0.327**
Supplier partnership		0.041	0.070	0.075		−0.070	−0.101	−0.059
Customer partnership		0.090	0.061	0.080		−0.019	−0.007	−0.022
Competitor partnership		0.016	−0.004	0.032		0.008	−0.009	0.013
URI partnership		0.171†	0.176†	0.218*		0.198*	0.225*	0.214*
Marketing capability × customer partnership			0.281**					
Manufacturing capability × supplier partnership							0.207*	
R&D capability × URI partnership				0.140				0.046
Firm age	−0.111	−0.015	0.002	−0.003	−0.425**	−0.287*	−0.221†	−0.283*
Firm size	0.028	−0.041	−0.075	0.015	0.269†	0.180	0.109	0.199
Sale growth	0.141	0.102	0.124	0.087	0.073	0.016	−0.027	0.011
Net profit margin	0.177	0.039	0.046	0.022	0.240	0.118	0.142	0.112
Market share	0.188	0.090	0.135	0.093	0.045	−0.025	0.028	−0.024
Market turbulence	−0.130	−0.060	0.032	−0.059	−0.063	0.096	0.101	0.096
Technology turbulence	0.131	0.153	0.128	0.161	−0.071	−0.016	−0.025	−0.013
8 sub-industry dummies	Included	Included	Included	Included	Included	Included	Included	Included
Adjusted R^2	0.191	0.458	0.511	0.464	0.162	0.462	0.490	0.454
R^2	0.346	0.611	0.655	0.622	0.323	0.614	0.641	0.615
ΔR^2		0.265	0.045	0.012		0.290	0.027	0.001
F	2.224**	3.994***	4.547***	3.939***	2.006*	4.045***	4.262***	3.821***
ΔF		5.436***	7.117***	1.677		6.017***	4.108*	0.182

Two-tailed test: † $p<0.1$, * $p<0.05$; ** $p<0.01$; *** $p<0.001$. Standardized coefficients are reported. $N=79$.

ships, only URI partnerships have a significant effect on either product or process innovativeness. Hypothesis 2a is thus only partially supported while Hypothesis 2b is supported.

Model 3 shows that the interaction effect of marketing capability and customer partnership on product innovativeness is positive and significant. Similarly, Model 7 shows that the interaction effect of manufacturing capability and supplier partnership on product innovativeness is positive and significant. Thus, Hypothesis 3a and 3b respectively are supported. However, Models 4 and 8 show that the interaction effects of R&D capability and URI partnership on product and process innovativeness are positive but not significant. Hence, Hypothesis 3c is not supported.

We have also examined the differences in models by hierarchical regression, and the values of ΔR^2 and ΔF are listed in Table 2. Model 1 serves as the base model for Model 2, which in turn is the base for Models 3 and 4. Similarly, Model 5 is the base for Model 6, which in turn is the base model for Models 7 and 8. Our results show that, except Models 4 and 8, adding either the independent variables or the interaction terms statistically improves the model.

To gain further insights into the nature of the significant interaction effects between internal capability and external partnerships on product and process innovativeness, we plot the interactions based on the results obtained in Models 3 and 7 (Aiken & West, 1991). We define high level and low level consumer/supplier partnership based on one standard deviation, respectively, above and below the mean of the consumer/supplier partnership variable, while we define high level and low level of marketing/manufacturing capability based on, respectively, the maximum and minimum of the marketing/manufacturing capability variable. Figure 1 presents a positive relationship between marketing capability and product innovativeness for a high level of consumer partnership, while a slightly negative relationship between marketing capability and product innovativeness for a low level of consumer partnership. Figure 2 reveals a positive relationship between manufacturing capability and process innovativeness for both high and low levels of supplier

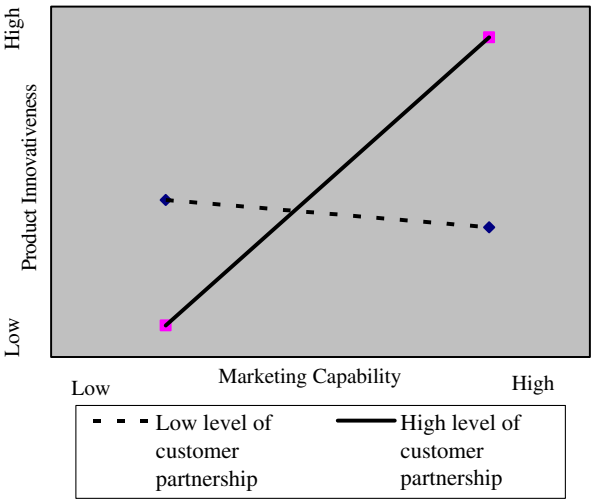

Figure 1 Interaction between marketing capability, customer partnership, and product innovativeness

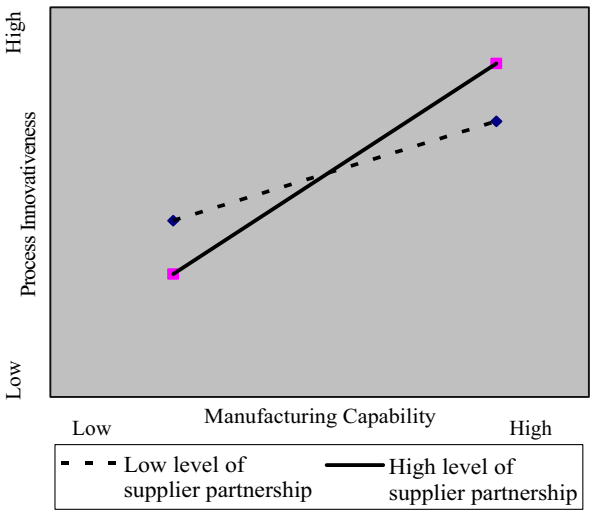

Figure 2 Interaction between manufacturing capability, supplier partnership, and process innovativeness

partnership, while the slope of the line that describe the positive relationship between manufacturing capability and process innovativeness for a high level of supplier partnership is significantly different from a low level of supplier partnership.

Discussion

Contributions

Using the theoretical arguments of exploitation and exploration, we develop an integrative model linking the impact of both internal capabilities and external partnerships on product and process innovativeness, and test the model on Taiwanese biotechnology firms. Overall, four contributions emerge. First, we contribute to the literature of both product and process innovativeness. Given the association between different types of innovations, studying either product or process innovations alone may lead to biased results as the effects of the other type of innovations have not been controlled for. This article contributes to the development of an integrative model for innovation by theoretically establishing and empirically testing the impacts of *both* internal capabilities and external partnerships on product and process innovativeness. Our results show that the three types of capabilities and URI partnerships have significant effects on innovativeness. In addition to exploiting their existing capabilities, firms may especially benefit from their partnerships with URIs for generating innovative ideas.

Second, our findings call for an integration of functional competences into performance outcomes. Consistent with Danneels (2002), both R&D and marketing capabilities are found to have significant effects on product innovativeness. In addition, our results indicate that process innovativeness depends on the *joint* exploitation of R&D and manufacturing capabilities. Our finding that only URI partnerships have a significant effect on either product or process innovativeness is

also interesting. This finding is consistent with prior research in this industry (George et al., 2002).

Third, in addition to the main effects, our results suggest the existence of synergy between internal capabilities and external partnerships. In particular, when a capability and a partnership are closely related with respect to the type of innovation concerned, the synergy effect can be salient. We have identified two such interactive influences, namely, (1) the interaction effect of marketing capability and customer partnerships on product innovativeness as well as (2) the interaction effect of manufacturing capability and supplier partnerships on process innovativeness. While O'Reilly and Tushman (2004) stress the importance of an appropriate balance between exploitation and exploration, our finding suggests that firms should also pay attention to the synergy that can be generated from a suitable combination of exploitative and explorative activities.

Finally, our study sheds light on the factors affecting innovation in the biotechnology industry of a non-Western country. Bartholomew (1997) suggests that country-specific institutional features affect national patterns in innovation. Since most of the prior studies of biotechnology firms are conducted in Western countries, the generalizability of their findings to non-Western settings is not certain (Meyer, 2007). Our study contributes to filling this gap of knowledge. Specifically, biotechnology firms in Taiwan, given their relative weakness in product innovativeness globally, may focus more on process innovativeness, thus providing an ideal context for more balanced consideration of both types of innovativeness in our study.

Limitations and future directions

In terms of limitations, first, our study has the usual trappings associated with survey research. Although our post hoc checks find little trace of common method variance problem, we cannot completely rule out its potential influence in self-report-based research (Podsakoff et al., 2003; Podsakoff & Organ, 1986). To overcome this problem, future research may need to tap into secondary data sources or combine survey data with secondary data.

Second, our total sample size, based on 84 respondents from 79 firms, is limited. While we did our best to increase our sample size, the limited number of Taiwanese biotechnology firms (a total of 187 that were listed in an official directory and were contacted by us) and the relatively high response rate (40.38%) have made it difficult to increase the sample size further. Future work may survey firms in the biotechnology and other industries in larger economies such as China and the United States to yield a larger sample size.

Third, the cross-sectional nature of our investigation remains a potential concern. Future research may use a longitudinal design by examining the dynamics between internal and external sources of innovation across a period of time. Although there may be synergy between internal and external sources of innovation, it will be interesting to examine whether strong internal capabilities will lead to less reliance on building external partnerships over time. A comparison between young and old firms in the same industry may also throw light on this issue.

Lastly, although URI partnerships are found to have a greater impact than the other types of partnerships on product and process innovativeness, the synergy effect

of R&D capability and URI partnerships on innovation is not significant. According to Owen-Smith, Riccaboni, Pammolli, and Powell (2002), there are different institutional structures in the United States and Europe governing university–industry relations in the biotechnology industry. Similar to Europe, the university–industry link in Taiwan is not as strong as in the United States. Thus Taiwanese biotechnology firms may not gain much from their URI partnerships in terms of strengthening their R&D capability. In brief, this finding may be country specific and further research in other countries is needed (Lu et al., 2008).

Conclusion

In conclusion, it is the combination of a firm's internal capabilities and external partnerships that impacts its innovativeness. Thus, a strategic theory of the firm (Stieglitz & Heine, 2007) should not only analyze the exploitation of existing internal capabilities and the exploration of new resources across organizational boundaries via partnerships with various players, but also probe deeper into their *combined* impact on firm performance such as innovativeness.

Appendix 1

Table 3 Questionnaire items[a].

Construct	Cronbach α	Questionnaire item
Dependent variables		
Innovativeness		
Product	0.82	Frequently enhancing product quality
		Frequently enhancing product competitiveness
		Frequently increasing market share of product
		Frequently enhancing reputation of company and brand awareness
		Frequently enhancing product profitability
Process	0.86	Frequently introducing new technology to improve manufacturing process or operational process
		Frequently acquiring new tools or facilities to enhance production or work efficiency
		Frequently generating new methods for improving manufacturing process or operational process
		A great deal of profits coming from new development of products or services
		Quicker manufacturing process design of products than competitors
Independent variables		
Capability		
R&D	0.83	Better product (or service) R&D capability than competitors
		Better capability to continually improve product (or service) functions or types than competitors
		Quicker launch or commercialization of new products (or services) than competitors
		More unique product (or service) features than competitors

Table 3 (continued).

Construct	Cronbach α	Questionnaire item
Marketing	0.93	More efficient operation of the distribution system of products (or services) than competitors
		Better marketing or sales capability than competitors
		Better reputation for customer service and product logistic support than competitors
		More customer oriented than competitors
Manufacturing	0.85	More flexible response to capacity changes than competitors
		Lower cost of mass production than competitors
		More efficient production system than competitors
		Lower cost of operation than competitors
Partnership		
Supplier	0.90	Frequent discussions and communications
		Frequent interactions for generating new product ideas
		Frequent interactions for developing new products
		Frequent interactions for testing of new products together
Customer	0.89	Frequent discussions and communications
		Frequent interactions for generating new product ideas
		Frequent interactions for developing new products
		Frequent interactions for testing of new products together
Competitor	0.93	Frequent discussions and communications
		Frequent interactions for generating new product ideas
		Frequent interactions for developing new products
		Frequent interactions for testing of new products together
URI	0.93	Frequent discussions and communications
		Frequent interactions for generating new product ideas
		Frequent interactions for developing new products
		Frequent interactions for testing of new products together
Control variables		
Firm-level characteristics		
Firm age		Number of years since founding
Firm size		Number of employees in the company
Sales growth		Very satisfied with the sales growth of the company
Net profit margin		Very satisfied with the net profit margin of the company
Market share		Very satisfied with the market share of the company
Industry-level characteristics		
Sub-industry		Nine industry categories of biopharmaceuticals, pharmaceuticals, diagnostic agents, biomedical materials, Chinese medicine, dietary supplements, agriculture, biotech services, and others
Market turbulence	0.81	High uncertainty of the consumer pattern
		High uncertainty of the consumer preference
		High uncertainty of the potential market
		High uncertainty of the future market demand
Technology turbulence	0.83	High uncertainty of the functions of new technology
		High uncertainty of the safety of new technology
		High uncertainty of the environmental impact of new technology
		High uncertainty of the future technological development of the industry

[a] All items, except firm age and size, were based on seven-point Likert scales, ranging from (1) "strongly disagree" to (7) "strongly agree," while each of firm age and size was measured by an indicator with seven intervals.

Appendix 2

Table 4 Factor analysis.

Scales and items	Factors (loadings)						
	R&D	Marketing	Manufacture	Supplier	Customer	Competitor	URI
Capability							
Better product (or service) R&D capability than competitors	0.84						
Better capability to continually improve product (or service) functions or types than competitors	0.88						
Quicker launch or commercialization of new products (or services) than competitors	0.67						
More unique product (or service) features than competitors	0.68						
More efficient operation of the distribution system of products (or services) than competitors		0.85					
Better marketing or sales capability than competitors		0.90					
Better reputation for customer service and product logistic support than competitors		0.89					
More customer oriented than competitors		0.83					
More flexible response to capacity changes than competitors			0.45				
Lower cost of mass production than competitors			0.89				
More efficient production system than competitors			0.81				
Lower cost of operation than competitors			0.86				
Partnership							
Frequent discussions and communications				0.74			
Frequent interactions for generating new product ideas				0.85			
Frequent interactions for developing new products				0.89			
Frequent interactions for testing of new products together				0.86			

Table 4 (continued).

Scales and items	Factors (loadings)						
	R&D	Marketing	Manufacture	Supplier	Customer	Competitor	URI
Frequent discussions and communications					0.85		
Frequent interactions for generating new product ideas					0.81		
Frequent interactions for developing new products					0.86		
Frequent interactions for testing of new products together					0.86		
Frequent discussions and communications						0.83	
Frequent interactions for generating new product ideas						0.84	
Frequent interactions for developing new products						0.94	
Frequent interactions for testing of new products together						0.93	
Frequent discussions and communications							0.90
Frequent interactions for generating new product ideas							0.91
Frequent interactions for developing new products							0.91
Frequent interactions for testing of new products together							0.89

Note: Only pattern matrix coefficients with absolute value greater than 0.40 are shown.

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Yu-Shan Su (PhD, National Taiwan University) is an assistant professor of international business at Chang Jung Christian University, Tainan, Taiwan. She was a Fulbright scholar at the University of Texas at Dallas in 2006–2007. Her research interests are innovation management in the biotechnology industry. She has published in the *Asia Pacific Journal of Management*, *Technological Forecasting & Social Change*, and others.

Eric W. K. Tsang (PhD, University of Cambridge) is an associate professor at the University of Texas at Dallas. He is a Senior Editor of *Asia Pacific Journal of Management*, and is on the editorial boards of five other journals, including the *Academy of Management Journal* and *Academy of Management Review*. He has published over 50 journal articles.

Mike W. Peng (PhD, University of Washington) is the Provost's Distinguished Professor of Global Strategy at the University of Texas at Dallas. As Editor-in-Chief, he has led the *Asia Pacific Journal of Management* to be accepted by the Social Sciences Citation Index (SSCI). He has published two leading textbooks, *Global Strategy* (1st edition, 2006; 2nd edition, 2009) and *Global Business* (1st edition, 2009).