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How does the second-order learning process moderate the relationship between innovation inputs and outputs of large Korean firms?

Hyojung Kim · Namgyoo K. Park · Jeonghwan Lee

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Abstract We investigate how the second-order learning process moderates the relationship between innovation performance and two types of knowledge seeking behavior, namely exploration and exploitation. We reinvestigate the second-order learning process of the top 100 Korean firms from 1997 to 2007 by capturing CEO turnover, board turnover, and R&D alliances. We argue that the current findings about exploration and exploitation should be reclassified in terms of innovation input and output. We suggest that researchers investigate the organizational learning process to understand the link between innovation inputs and outputs. Our empirical results show that while innovation inputs are not related to exploratory outputs, the second-order learning process reshapes the relationship between both exploration/exploitation type innovation inputs and exploratory innovation outputs, and that the new focus of organizational learning process can refine current innovation literature.

Keywords Exploration · Exploitation · Second-order learning · Innovation

How do exploration- and exploitation-type knowledge seeking activities affect innovation outputs? To answer this question, the existing literature has applied somewhat inconsistent criteria to distinguish exploration and exploitation activities, and has

H. Kim
Department of International Trade and Business, College of Business Administration, Sangmyung University, Insakwan S221, 20 Hongjimun 2-Gil, Jongno-Gu, Seoul 110-743, Korea
e-mail: hjkim@smu.ac.kr

N. K. Park
Department of Strategy and International Business, Graduate School of Business, Seoul National University, SK-Hall 308, San 56-1 Sillim-Dong, Gwanak-Gu, Seoul 151-916, Korea
e-mail: npark@snu.ac.kr

J. Lee (✉)
Department of International Trade, College of Business Administration, Myongji University, 4307-2Ho Kyongsangkwan, 34 Geobukgol-Ro, Seodaemun-Gu, Seoul 120-728, Korea
e-mail: tankee@mju.ac.kr

subsequently delivered mixed findings to various fields of strategic management (e.g., Benner & Tushman, 2003; Holmqvist, 2004; Levinthal & March, 1993; Lu, Tsang, & Peng, 2008; McGrath, 2001; Raisch, Birkinshaw, Probst, & Tushman, 2009; Sidhu, Commandeur, & Volberda, 2007; Siggelkow & Rivkin, 2006; Su, Tsang, & Peng, 2009; Zhou & Li, 2007). In particular, previous studies of exploration and exploitation have relied on their own definitions (see Table 1 for examples) and heterogeneous antecedents, moderators, and performance indexes (e.g., Gupta, Smith, & Shalley, 2006; Lavie, Stettner, & Tushman, 2010; Li, Vanhaverbeke, & Schoenmakers, 2008; Raisch & Birkinshaw, 2008). Most of these studies were based on an implicit assumption that a certain form of knowledge creation inputs, whether exploration or exploitation, may lead to the same form of knowledge creation outputs.

Transforming a large sum of knowledge creation inputs (e.g., massive investments in R&D activities) into meaningful innovation outputs requires processes of internal management that are both delicate and complex (Ahlstrom, 2010; Choi & Williams, 2012; Pisano & Shih, 2009; Tippins & Sohi, 2003; Zhang, Li, Hitt, & Cui, 2007). As Pisano and Shih (2009) pointed out, large input of knowledge creation investments alone does not automatically lead to better innovation outputs. Tippins and Sohi (2003) also argued that organizational learning is one of the most critical determinants which affect the association between investments in information technology and organizational efficiency. Thamhain (2003) emphasized the role of organizational contexts in satisfying individual members. Bierly and Chakrabarti (1996) argued that organizational characteristics such as strategic flexibility can moderate the relationship between technological learning and new product development. Although many studies have investigated the relationship between R&D inputs and innovation outputs, only a few have focused on the internal transformation process linking knowledge creation inputs and outputs (Laursen & Salter, 2006; Morbey, 1988, 1989; Sarkar, Echambadi, Agarwal, & Sen, 2006).

Highlighting the sequential steps of knowledge creation inputs, internal process, and innovation outputs, we investigate how determining whether inputs are exploration or exploitation type may refine the current findings regarding the way innovation inputs become innovation outputs (remaining the same or transforming into a completely different type). We also examine how one of the internal learning processes, the second-order learning process, can reinforce or reshape the relationship between exploration-type inputs and outputs, and between exploitation-type inputs and exploration-type outputs. Lant and Mezias (1992) defined the second-order learning process as the exploration of alternative routines, rules, technologies, goals, and purposes instead of just learning how to repeat current routines with more efficiency, while the first-order learning process as routines, incremental, conservative processes that serve to maintain stable relations and sustain existing rules. We test our hypotheses by focusing on the top 100 Korean firms during the years 1997–2007, as these show substantial variation in terms of innovation inputs, internal learning processes, and innovation outputs. Our empirical results show a negative relationship between both exploration/exploitation-type inputs and exploration-type outputs, but that once the relationship is moderated by second-order learning processes, the negative relationship is reshaped. In terms of exploration-type outputs, second-order learning processes proved to be beneficial in making exploration/exploitation-type inputs meaningful.

Table 1 A review of exploration and exploitation studies

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Anand, Mesquita, & Vassolo, 2009	Firm	Biopharmaceutical firms' competitive dynamics patterns	Entry & exit, respectively, as the events of investing in or divesting from research for a new product technology that may/may not lead to a viable product in the future in a given market	Entry & exit, respectively, as the events of starting & ceasing sales activities of existing products in a given market	Firms follow different reasoning in 2 domains; as a result competitive dynamic patterns differ for exploitation & exploration
Andriopoulos & Lewis, 2009	Firm	5 firms in computer & consumer products	New opportunities to foster more radical innovation	Existing products to enable incremental innovation	Assuming trade-off relationship of explorations & exploitation, suggest how integration & differentiation manage this paradox
Audia & Goncalo, 2007	Individual	1,665 patents of inventers	Divergent creativity, the search for knowledge that departs from an established direction, the potential generation of a completely new principle	Incremental creativity, continuity with existing solutions, improvement through modification, & generating ideas within an established framework	Examining the exploitation-exploration trade-off at the individual level. Individual's past success leads to bring exploitation not exploration
Auh & Menguc, 2005	Firm	260 firms in manufacturing industries in Australia	Concerned with challenging existing ideas with innovative & entrepreneurial concepts	Chiefly interested in refining & extending existing skills & capabilities	Benefit by balancing exploration & exploitation when competition intensifies differently affects prospectors & defenders. The resources distribution needs to consider the dominant learning mode of the firm

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Beckman, 2006	Project team	170 young high-tech firms	Effort to win technology race in a new niche or to gain competitive advantage by being first to develop new, unproven technologies	Build upon existing products, & technologies, & efforts to seek competitive advantage through technical enhancements or cost advantages	Founding team composition members' prior company affiliations shapes exploration. Ambidextrous firms whose founding teams have both common & diverse prior company affiliation are more likely to grow
Beckman, Haunschild, & Phillips, 2004	Firm/Network	300 largest US firms during 1988–1993	Form new relationship with new partner. Expanding to new network partners. Experimenting with new alternatives	Form additional relationships with existing partners. Reinforcing & refining additional relationships with existing partners	Exploration or exploitation is chosen depending on type of uncertainty that firms are facing: firm-specific, market-level uncertainty. Assumption of two different modes
Benner & Tushman, 2002	Firm	Photography & paint industry	Distant search can be extended by characterizing an organization's innovative activity	Anchored in existing firm knowledge	Impact of process management activities on technological innovation enhance incremental innovation at expense of exploratory innovation
Benner & Tushman, 2003	Firm	Conceptual	Radical innovations or those for emergent customers or markets are exploratory, since they require new knowledge or departures from existing skills	Incremental technological innovations & innovations designed to meet needs of existing customers are exploitative & build on existing organizational knowledge	Process management activities buffered from exploratory activities & ambidextrous organizational forms provide complex contexts for coexisting of exploration & exploitation

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Bierly & Daly, 2007	Firm	98 manufacturing firms	Creation or acquisition of new knowledge	Ability to leverage existing knowledge to create new organizational products & processes	Exploration & exploitation are separate & complementary constructs. Simultaneously pursing 2 has negative performance
Bierly, Damanpour, & Santoro, 2009	Firm	180 firms working with University Research Center (URC)	Application of external knowledge to produce new products & technologies	Application of the external knowledge to refine organization's existing products & improve its processes	Organizational conditions that facilitate application of knowledge transferred from URCs to develop exploratory & exploitative innovations in the recipient firm are different
Burgelman, 2002	Firm	1 high-tech company	Variation increasing strategy process-autonomous	Variation reducing strategy process-induced	Balancing exploration & exploitation strategy process through coevolutionary lock in approach
Cao, Gedajlovic, & Zhangm, 2009	Firm	122 firms in high-tech industries	Following He & Wong (2004)	Following He & Wong (2004)	Balance dimension of ambidexterity & combined dimension of ambidexterity enhance firm performance
Cao, Maruping, & Takeuchi, 2006	Firm	Conceptual	Firms' abilities to search for & identify new opportunities, discover new knowledge, experiment with new experiences, & seek variation in strategy	Firms' abilities to execute & refine their existing routines, appropriate value from existing knowledge, & strengthen existing advantages	CEO's embededness in interfirm social networks linked to firms' exploration; CEO's embeddedness in intrafirm social networks linked to both exploitation

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
					& exploration. Implicit assumption of ambidexterity
Cegarra-Navarro, 2007	Firm	139 firms in Spanish optometry sector	Variation, risk taking, experimentation, play, flexibility, discovery, innovation	Refinement, choice, production, efficiency, selection, implementation, execution	New ideas & actions flow from individual to organization through relationship memory which is a bridge between exploration & exploitation
Danneels, 2002	Firm	5 high-tech firms producing physical B2B products	Learning activities that lead to the addition of new resources	Learning activities involving the use of resources the firm already has	Simultaneously considering exploitation & exploration of customer & technological competences
Dittrich, Duysters, & de Man, 2007	Firm/Alliance network	1 case of IBM	Strategies aimed at innovating & business development	Strategies primarily directed at making the most of existing competences	Networks needed to achieve 2 different objectives of exploration & exploitation. Strategic change is facilitated by changing the company network from exploitation towards exploration
Dixon, Meyer, & Day, 2007	Firm	4 privatized Russian oil companies	March's definition & leads to strategic flexibility	March's definition & leads to operational capabilities	Exploitation & exploration learning do not coexist in initial stages of organizational transformation in transition economies but are sequential
Fang & Levinthal, 2009	Firm	Simulation model	No specific statement	No specific statement	Trade-off between exploration/ exploitation, in multi stage, exploitation lead to an

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
					immediate decline in payoffs, exploratory behavior has value
Geiger & Makri, 2006	Firm	208 manufacturing companies	Experimentation with new alternatives whose returns are uncertain, distant, & often negative	Refinement & extension of existing competencies & technologies exhibiting returns are positive, proximate	Available slack affects process of innovation by facilitating process of exploration & exploitation
Gibson & Birkinshaw, 2004	Business unit	4,195 individuals in 41 business units	Adapting effectively to changing environmental demands	Alignment in its current operations	Alignment, adaptability, & their interaction significantly & positively correlated with performance
Gilsing & Nooteboom, 2006	Sector	Pharmaceutical biotechnology	Development of novel capabilities is needed to survive in the long term	Efficient employment of current assets & capabilities is needed to survive in the short term	Suggest 'cycle of discovery'; how exploitation & exploration are managed; how exploration builds on but also shifts existing systems of exploitation. Implicit assumption of trade-off relationship
Graebner, 2004	Firm	8 acquisitions	Integration promotes recombination of the acquired firm's resources	Autonomy promotes completion of the acquired firm's existing technology	Simultaneously sustaining both exploration & exploitation is necessary for organizational survival. Acquisition can be a means for simultaneous pursual of exploration & exploitation
Greve, 2007	Firm	11 firms in Japanese shipbuilding industry from 1971–2000	Extent of exploration is in an innovation launch as its technological &		Reductions in performance increased the rate of making exploration innovations as well as that of exploitation

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
			market novelty for the focal firm		innovations, & at the same time. No direct trade-off of between exploration & exploitation rates
Groysberg & Lee, 2009	Individual	799 equity analysts, 254 fixed-income analysts across 78 firms	Seeking change in response to internal strategy or external constraints	Improving efficiency, delivery, or profitability of the existing business model	Individuals, much as firms, experience greater difficulty in terms of their performance when they explore a new market than when they exploit an established one. Examining tension of exploration & exploitation
Haas, 2006	Project teams	96 project teams at international development agency	Exploration activities focused on gathering knowledge from experts or document sources outside the team provide external knowledge for the team	Focusing knowledge by applying it to improve project performance	Exploration & exploitation processes are closely intertwined for many project teams in contemporary knowledge-intensive organizations. Same team members play across different elements of the exploration & exploitation processes
He & Wong, 2004	Firm	206 manufacturing firms in Singapore & Malaysia	Technological innovation activities aimed at entering new product-market domains	Technological innovation activities aimed at improving existing product-market positions	Interaction between exploratory & exploitative innovation strategies is positively related to sales growth rate. Imbalance between exploratory & exploitative innovation is negatively related to sales growth rate

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Holmqvist, 2004	Firm	Scandinavian PC Systems between 1997–1999	Creates variety in experience through search, discovery, novelty, innovation, & experimentation	Creates reliability in experience through refinement, routinization, production, & implementation of knowledge	Suggesting how exploitation is interrelated with exploration within & between organizations. Dissatisfaction with either an exploitative or an exploratory behavior generates transformation of ongoing behavior
Im & Rai, 2008	Firm	US Logistics industry (238 customer, 76 vendor)	Pursuit of new knowledge & opportunities, the returns of exploration are uncertain	Use & refinement of existing knowledge, & the returns to exploitation are certain & reliable	Sustained performance of long-term interorganizational relationships hinges upon simultaneous exploration & exploitation that are enabled by IT design & organization design for the relationship
Jansen,Van Den, & Volberda, 2006	Firm	283 units from 115 branches of European financial services firm	Innovation captures extent to which units depart from existing knowledge & pursue innovations for emerging customers or markets	Innovation captures extent to which units build on existing customers	Formal hierarchical structure differentially influences exploratory & exploitative innovation. Ambidextrous organizations might differentiate coordination mechanisms at organizational unit level
Kane & Alavi, 2007	Firm	Agents based simulation model	Development of new knowledge or replacing existing content with in the organization's memory	Incremental learning focused on diffusion, refinement, & reuse of existing knowledge	Qualifying March's argument, IT-enabled learning mechanisms enable capabilities that have a distinct effect on exploration & exploitation

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Katila & Ahuja, 2002	Firm	124 industrial robotics companies	Search scope is defined as the degree of new knowledge that is explored	Search depth is defined as the degree to which search revisits a firm's prior knowledge	Interaction between exploration & exploitation will have a positive impact on new product development
Kim & Rhee, 2009	Firm	Agents based simulation model	Search, variation, risk taking, experimentation, play, flexibility, discovery, innovation	Refinement, choice, production, efficiency, selection, implementation, execution	Extending March's model by conceptualizing environmental dynamism & articulating notion of internal variety in an organization
Kogut & Kulatilaka, 2001	Firm	Conceptual	Looking for variations on new techniques & new markets	Refinements of existing processes	Paradoxical conclusion to sustained application of financial modeling to firms; fundamental basis of the value of the firm is its organizational capability to exploit current assets & explore future opportunities
Koza & Lewin, 1998	Alliance	Conceptual	Exploration alliance involves a desire to discover new opportunities	Exploitation alliance involves & joint maximization of complementary assets by sharing in residual returns from a business activity	Alliance intent described as having either an exploitation or exploration objective & this intent may co-evolve with changes in strategy, environmental cognition, & managerial preferences
Lavie & Rosenkopf, 2006	Alliance	337 US software firms from 1990–2001	Search, variation, risk taking, experimentation, play, flexibility, discovery, innovation	Refinement, choice, production, efficiency, selection, implementation, execution	Internal pressures for exploration & exploitation constrain firms' expected learning behaviors within domains

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
					Firms balance their tendencies to explore & exploit with respect to nature of their alliances or choice of partners over time & across domains
Lazer & Friedman, 2007	Network	Agents based simulation model	Maintaining information diversity	Maintaining information diffusion	Trade-off between exploration & exploitation in efficient network, but both positively link to performance
Lee, Lee, & Lee, 2003	Network	Simulation model	Provide better opportunity in the long run. Require scare resources that could be better used for enhancing the firm's market position	An existing technology to ensure firm's immediate survival. Myopic choice	Exploration likely to increase the chance of firm growth when there are a number of power users or when a new technology is introduced before an established technology takes off
Levinthal & March, 1993	Firm	Conceptual	Pursuit of new knowledge	Use & development of things already known	Survival requires a balance; precise mix of exploration & exploitation that is optimal is hard to specify
Lewin, Plong, & Carroll, 1999	Firm/Industry	Conceptual	Increases likelihood of achieving performance levels significantly above or below historical trend line. Exploration involves searching for, indentifying, &	Is likely to maintain the historical performance trend line. Exploitation adaptations are directed primarily toward incremental improvement of existing capabilities & efficiency	The cumulative effect of exploitation & exploration adaptations is reflected in the firm's legacy. Organizations increase, deplete, or enhance their legacy through the cumulative effect of

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
			investing in new opportunities & has potential to expand & replenish legacy		their exploration & exploitation activities as mediated by their absorptive capacities to assimilate new knowledge
Lin, Yang, & Demirkan, 2007	Alliance	95 firms in pharmaceutical, computer, food, steel, paper industries	Expanding a firm's network boundary through new alliance partners	Consolidating firm's network through existing partners	Ambidexterity approach in alliance formation does not always guarantee increased economic benefits for firms. Positive when there are large firms, uncertainty, firm centrality, structural holes, young network
Lubatkin, Simsek, Ling, & Veiga, 2006	Firm	139 firms in medium sized, TMT level	Involves a bottom-up learning process in which senior managers are persuaded to abandon their old routines & make a commitment to a new course of action	Involves a top-down learning process in which senior managers move to institutionalize routines & behaviors best suited for refining current competencies	TMT behavior integration link to ambidextrous orientation & ambidextrous orientation link to good performance
Lunnan & Barth, 2003	Project team	4 projects teams in 2 firms	Developing something new	Refining what is known	Production-oriented teams have opportunities for exploratory learning & very innovative-oriented teams need to worry about exploitation. Sequential learning approach of exploration & exploitation

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
March, 1991	Firm	Agents based simulation model	Search, variation, risk taking, experimentation, play, flexibility, discovery, innovation	Refinement, choice, production, efficiency, selection, implementation, execution	Refining exploitation more rapidly than exploration are likely to become effective in the short run, self-destructive in the long run
March, 2006	Firm	Conceptual	Following March (1991)	Following March (1991)	Qualifying March's (1991) argument, emphasizing the role of exploration for survival
McGrath, 2001	Project team	56 exploratory projects, situated in large companies	Critical to the capacity of an organization to create variety, to adapt		Firm survival has to do with the competitive effects of exploration. Organizational learning was more effective when the projects operated with autonomy with respect to goals & supervision
Mcnamara & Badden-Fuller, 2007	Firm	178 bio-pharmaceutical firms	Basic research has less certain outputs, longer time horizons, & more diffuse effects than further development of existing ones	Generating certainty, speed, proximity, & clarity of feedback ties exploitation to its consequences more quickly & precisely	Investors respond positively at every stage of exploration & exploitation continuum, but there are differences between small & large firms
Miller, Zhao, & Calantone, 2006	Firm	Agents based simulation model	Search, variation, risk taking, experimentation, play, flexibility, discovery, innovation	Refinement, choice, production, efficiency, selection, implementation, execution	Extending March's model by allowing for direct interpersonal learning, locating individuals between local & distant search relevant, & recognizing tacit dimension of knowledge

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Mom, Van Den Bosch & Volberda, 2007	Individual, Firm	104 managers top 10 electronic industry	Creating variety in experience, broadening a manager's existing knowledge base, searching for new organizational norms, routines, structures, & systems	Creating reliability in experience, deepening a manager's existing knowledge base, using & refining their existing knowledge	Different influence of managers' knowledge inflows on managers' exploration & exploitation activities. Exploration & exploitation are 2 separate dimensions, but managers may combine both
Mom, Van Den Bosch, & Volberda, 2009	Individual, Firm	458 managers of 3 large multi-unit firms	Variety increasing activities	Reliability enhancing activities	Formal organization structure indicate that managers' decision making authority positively relates to managers' ambidexterity, formalization of managers' tasks has no significant relationship with ambidexterity
Nemanich, Keller, & Vera, 2007	Project team	Conceptual	Emphasize variation toward the development of radical innovations aimed at entering new product-market domains	Emphasizes relatively incremental changes to existing products & cost reduction efforts, increasing market appeal	Top managers play a critical role in shaping a firm's innovation trajectory & managing dynamic balance between innovation & efficiency across time & space
Nerkar, 2003	Firm	15,345 patents for 1981–1987 for 33 firms, pharmaceutical industry	Temporal exploration: creation of new knowledge through recombination of older knowledge obtained by examining a wider time spread	Temporal exploitation: creation of new knowledge through a recombinant process that emphasizes recency	Balancing current knowledge with knowledge available across large time spans is an important factor of new knowledge impact. Simultaneous exploration & exploitation may not lead to benefits for firm

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Nooteboom, Haverbeke, Duyster, Gilsing, & Oord, 2007	Firm, Alliance	116 firms, 994 alliances	Following March (1991), experimentation with new alternatives	Following March (1991), refinement & extension of existing technologies	In exploration or exploitation, cognitive distance differently affects innovation performance. Implicit assumption of ambidexterity
Perretti & Negro, 2006	Project team	all 6,918 feature films produced from 1929–1958	Proportion of new member, new combinations		Status differentiation of team members & organizational hierarchies affect the exploration/exploitation trade-off in team composition (U-shape)
Quintana-Garcia & Benavides-Velasco, 2008	Firm	985 patent data from biotechnology firms	Ability to perform extensive searches that result in novel methods or materials technologically distant from existing innovations	Exploitation improves methods or materials	Scope of technological resources has a stronger effect on exploration than on exploitation. Changing nature of innovation requirements embedded in technology cycles. Firms develop capabilities to balance exploration & exploitation
Rivkin & Siggelkow, 2007	Firm	NK simulation model	No specific statement		Suggesting healthy balance of exploration & exploitation. Introducing interaction patterns for deciding how much to invest in long run exploratory efforts

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Rosenkopf & Nerkar, 2001	Firm	2,333 patent data in optical disk technology	Boundary spanning, the ability of a firm to create new knowledge through recombination of knowledge across boundaries		Exploration beyond organizational boundaries obtained more impact than within boundaries. In balancing between building on similar & different technology, managers face trade-offs between domain & overall
Rothaermel & Deeds, 2004	Alliance	325 biotechnology firms	Exploration alliances are entered into with motivation to discover something new; focus on the 'R' in R&D process	Exploitation alliances focus on the 'D' in R&D process & are entered into with the goal to join existing competencies across organizational boundaries to generate synergies, which are then shared across the partners	Firm's competency currently exploited must have been explored at some earlier time. Exploration alliances predicting products in development, which in turn predict exploitation alliances & that concludes with exploitation alliances leading to products on the market
Sidhu, Commandeur, & Volberda, 2007	Firm	850 Dutch metal & electrical engineering sector	Greater or lesser amounts of search in nonlocal domains external to the organization. Nonlocal-local search in 3-dimensional supply, demand, & geographic space		Exploration-exploitation orientation is positive with innovativeness. Greater nonlocal demand-side search hurts innovativeness in dynamic circumstances, greater spatial search has positive effect on innovativeness

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Sidhu, Volberda, & Commandeur, 2004	Firm	155 Dutch metal & electrical engineering sector	External information acquisition; supply-side information-acquisition, demand-side information-acquisition, & geographic information acquisition		More environmental dynamism, a stronger organization mission, a prospector orientation & larger slack resources are associated with a greater exploration orientation
Siggelkow & Levinthal, 2003	Firm	Agents based simulation model	No specific statement		Suggesting how different organizational structures moderate balance. Exploration & stability are not achieved simultaneously through distinct organizational features, but sequentially by adopting different organizational structures
Siggelkow & Rivkin, 2006	Firm	Agents based simulation model	Which alternatives a department manager can consider is determined by the degree to which his or her rationality is bounded		In the structure of the ambidextrous organization, increased exploration at lower levels can backfire, reducing overall exploration
Smith & Tushman, 2005	TMT level, Firm	Conceptual	Variance-increasing activities, learning by doing, & trial & error	Variance-decreasing activities & disciplined problem solving	Sustained organizational performance is rooted in both exploring & exploiting, & is up to the senior team's ability to deal with the contradictions of exploring & exploiting

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Soosay & Hyland, 2004	Firm	1 engineering company in Australia	Activity for new knowledge, skills & processes	Activity of existing knowledge, skills & processes in terms of refinement & incremental improvement	As information from internal & external sources pervades the firm, knowledge is integrated into the business using both exploration & exploitation. Balancing trade-off relationship of exploitation & exploration requires contin uous reconfiguration of firm resources
Tayor & Greve, 2006	Project team	4,485 comic books with 234 publishers	Radical innovations characterized by prior uncertainty & posterior variance in performance	Incremental improvements increase average performance by using existing knowledge	Multiple knowledge domains produce novel combinations that increase the variance of product performance. Exploration & exploitation may be 2 different processes, experiences affects both positively. Ambidextrous teams are possible
Trieschmann, Dennis, Northcraft, & Nieme, 2000	Firm	Business schools	Academic constituency	Student & business constituency	Performance of exploration & exploitation is different. A healthly tension & well managing between them is needed
Tsang & Yip, 2007	Firm	FDIs made by major Singapore firms from 1980–2000	Resource-exploration FDI regarded as a means to acquire strategic assets, such as technology, management & marketing	Resource-exploitation FDI viewed as the transfer of an MNC's proprietary resources across borders	Economic distance does matter for FDIs in more developed & less developed countries. Supporting arguments for resource-exploitation or

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
			expertise, available in a host country		resource-exploration perspec tive. Assumption of ambidexterity
Uotila, Maula, Keil, & Zahra, 2009	Firm	279 manufacturing firms	Search, variation, risk taking, experimentation, play, flexibility, discovery, innovation	Refinement, choice, production, efficiency, selection, implementation, execution	Balance between exploration & exploitation provide optimal performance level
Van Looy, Martens, & Koenraad, 2005	Firm	Modeling	Presupposes more heterogeneous ones; implies conflict & a redefinition of identities	Benefits from homogeneous relational fields, thrives on consensus & can be seen as identity confirming	Adopting longer timeframes, ambidextrous firms can be superior to focused mature firms
Vermeulen & Barkema, 2001	Firm	25 firms for 20 years	Acquisitions may broaden a firm's knowledge base & decrease inertia	Greenfield to exploit of a firm's knowledge base eventually makes a firm simple & inert	Acquisitions may improve the viability of a firm's later expansions, both greenfields & acquisitions. Surviving firms strike a balance between exploitation & greenfields, & between organizational revitalization & acquisitions
Voss, Sirdeshmukh, & Voss, 2008	Project team	214 US sample of nonprofit professional theaters	Product exploration as organizational emphasis on introducing radical innovations that extend existing product competencies	Product exploitation as organizational emphasis on marketing existing or incrementally modified products that capitalize on existing product competencies	Internal & external factors force trade-offs between a strategic emphasis on product explora tion & a strategic emphasis on exploitation

Table 1 (continued)

Articles	Level	Sample	Conceptual definition		Findings for how to deal with exploration & exploitation
			Exploration	Exploitation	
Wadhwa & Kotha, 2006	Alliance	383 US telecommunication equipment manufacturing firms	CVC investment activity—investments to search for new opportunities in their external environments		Inverted U-shaped relationship between CVC investment & innovation. Firm investor involvement would strengthen relationship between number of CVC investments & rate of knowledge creation
Winter & Szulanski, 2001	Firm	Conceptual	In which the business model is created & refined	In which the business model is stabilized & leveraged through large-scale replication	Replicators naturally "front-loaded" with exploration. Next order of business is effective leveraging (exploitation) of that innovation, & success typically yields business success, at least in present value terms

Overall, this study makes three contributions. First, we emphasize that academic researchers need to consider the role of internal learning process in knowledge creation activities. Our study shows that a second-order learning process can effectively transform exploitation-type inputs into exploration-type innovation outputs. Thus, managing internal processes may sometimes be more critical than actual R&D investments inputs. Second, we provide guidelines to refine the inconsistent findings of previous studies. By distinguishing between types of knowledge creation inputs, we may answer whether mixed findings are caused by confusion between inputs and outputs or by fundamental differences in the heterogeneous contexts of each study. Third, our study suggests that the variance observed in the impact of second-order learning processes may depend on such organizational contexts as CEO turnover, board turnover, or R&D alliances. These findings provide new guidelines for reexamining the role of internal transformation processes in future knowledge creation studies.

Theoretical background and hypotheses

March (1991) provided a fairly broad distinction between exploration and exploitation. That is, exploitation activities include refinement, choice, production, efficiency, selection, implementation, and execution, while search, variation, risk taking, experimentation, play, flexibility, discovery, and innovation are categorized as exploratory activities. While this broad definition may have been a good foundation for active empirical research over the last two decades, it also made for a report of mixed outputs. Understanding exploration and exploitation as organizational learning processes that represent a sequential system of input, internal management, and output may be one of the possible solutions to resolve the inconsistent previous findings (Benner & Tushman, 2003; Greve, 2007; Nemanich, Keller, & Vera, 2007; Nerkar, 2003; Sidhu et al., 2007).

Many studies view exploration and exploitation as organizational learning processes (Gupta et al., 2006; Li, Chen, Liu, & Peng, 2012). Typically, organizational learning processes begin with scanning and searching, and move on to information access, interpretation, integration, knowledge creation, retention, and dissemination (Garvin, 1998). Exploration and exploitation, which are critical organizational learning processes, require an investment in input, including complex internal processes that integrate various inputs into meaningful outputs, and refining those outputs (Katila & Ahuja, 2002; Li et al., 2008; Sidhu et al., 2007). Once we identify exploration and exploitation as part of a sequential organizational learning process starting with input, internal process, and outputs, the final quality of output naturally depends on two critical factors: types of inputs and internal processes. Thus, if internal processes are not efficient or effective, exploitative inputs cannot guarantee an exploitative output. Similarly, exploratory inputs cannot always produce exploratory outputs.

Once we assume that internal processes are equal across firms, formatting input is the only critical determinant for output. In terms of input type, previous studies have classified investments for input as either exploration or exploitation activities (often labeled "exploration" for the sake of search scope and "exploitation" for search depth; Katila & Ahuja, 2002; Sidhu et al., 2007). According to March (1991), the exploitative

activity is more clear, precise, and focused on the near term than are exploratory activities. Organizations look for knowledge they can easily combine with existing knowledge bases, often characterized by lower risk rather than entirely different knowledge. For R&D activities, firms continually invest in local searching activities, by exploiting internal resources and reinforcing current R&D activities (Cohen & Levinthal, 1990; Griliches, 1998), as well as relatively distant searches through universities, research institutes, and alliances with other firms (Cohen, Nelson, & Walsh, 2002; Hagedoorn & Schakenraad, 1994).

R&D activities are a good indicator that organizations are pursuing exploratory learning activities. Companies continually invest in exploration-oriented R&D inputs while simultaneously performing activities that link R&D inputs to outputs. In most cases, inputs are identified as investment activities or resources in the hope to create new knowledge, while outputs are usually understood as newly created objects, such as new knowledge, patents, and/or products. Rosenkopf and Nerkar (2001) highlighted the pattern of R&D inputs which eventually determine output quality of innovation. They argued that when the search activity is centered on exploration, outputs are likely to be exploratory, especially explorations that seek knowledge across organizational and technological boundaries, usually expected to yield a positive impact on subsequent technological evolution. Lavie and Rosenkopf (2006) suggested that both exploration and exploitation have distinctive learning modes, eventually reinforcing the efficiency of their learning mechanisms. That is, search activities centered on exploratory R&D inputs often move into the internal learning process that is suitable for exploratory outputs. To successfully manage exploratory R&D inputs, firms may need to align internal knowledge transformation processes such as organizing new task force teams, adjusting evaluation and incentive structures, and accommodating innovation failures (Christensen, 2006; Rosenkopf & Nerkar, 2001). Developing the fine tuning processes to readjust internal processes and input formats tends to be path-dependent and accelerates over repeated experiences (Levitt & March, 1988). If the input is exploratory in its innovation process, the path-dependent nature of knowledge seeking behavior will constantly pursue newness and underline reorientation, while the output of the learning process will more likely be exploratory (Levitt & March, 1988).

Still, radically transforming the original quality and format of knowledge input of R&D activities is fairly demanding. Knowledge seeking activities can be costly, time-consuming, and path-dependent (Nelson & Winter, 1982). For example, when organizations pursue local search activities, they may end up improving their existing knowledge and experience only marginally (Almeida, Phene, & Grant, 2003; Lavie & Rosenkopf, 2006). Due to the organizational nature of inertia and the cost of exploring completely new knowledge, such learning activities may offer only incremental contributions rather than radical advancement. Rosenkopf and Nerkar (2001) showed that concentrating on local search for R&D inputs may lead to new but similar technology developments rather than radical innovations. In short, while activities following exploitative R&D inputs may improve existing knowledge bases through incremental changes, they may not create entirely new or radical knowledge. Therefore, we predict the following:

Hypothesis 1 Assuming that the internal processes are fairly equal across firms, the quality of innovation outputs is heavily dependent on the format of inputs.

Hypothesis 1a Assuming that the internal processes are fairly equal across firms, the exploratory innovation inputs will more likely produce exploratory innovation outputs.

Hypothesis 1b Assuming that the internal processes are fairly equal across firms, the exploitative innovation inputs will be less likely to produce exploratory innovation outputs.

In addition to the type of innovation inputs, R&D outputs are significantly dependent on organizational routines or internal learning processes (Pisano, 1994). Previous studies of R&D activities have shown that R&D inputs themselves do not automatically lead to successful innovation performance, leaving internal processes as a kind of black box (Powell, Koput, & Smith-Doerr, 1996; Rothaermel & Hess, 2007; Sampson, 2007). Internal learning processes such as collaboration patterns, strategic reorientation, knowledge acquisitions through M&As, and top management turnover may entirely reshape how an innovative idea is created, shared, and integrated and how it may successfully reach the markets. These internal learning processes include trial and error, experiential learning, risk-taking, cross-functional coordination, and consolidation of different technologies (Thamhain, 2003). Previous studies have highlighted the compatibility with organizational strategy (Westerman, McFarlan, & Iansiti, 2006), involvement and understanding of CEO's vision (Tushman, Anderson, & O'Reilly, 1997), and the position of an R&D team inside the entire organization and communication process (Van den Bulte & Moenaert, 1998).

Organizational learning that can achieve the strategic renewal and outcomes for the organization is classified into either first- or second-order learning processes (Lant & Mezias, 1992). A first-order learning process is an attempt to improve the proficiency or effectiveness of existing methods for current business, while second-order learning is a reorienting process where new routines, technologies, and goals are sought for the purpose of enhancing revenues and profits in the future. Previous studies have shown that innovative performance depends on the type of learning process and interactions between R&D inputs and learning process (e.g., Autio, Kanninen, & Gustafsson, 2008; Bierly & Chakrabarti, 1996; Virany, Tushman, & Romanelli, 1992). Exploitative inputs tend to increase the likelihood of an internal learning process for adopting exploitative procedures such as first-order learning (Teece, Pisano, & Shuen, 1997). This first-order learning process attempts to maintain consistency within the organization (i.e., staying as consistent as possible within existing rules by utilizing incremental change to improve existing strategies, structures, systems, etc.). Therefore, if input takes the form of exploitation, with the aim of achieving an incremental improvement, the organization will likely employ a first-order learning process.

A second-order learning process can alter underlying assumptions, the foundations of an organization, and experiments on activities requiring new decision making (Virany et al., 1992). Pisano and Shih (2009) suggested that managers need to creatively integrate their disciplines, fields, and organizations to produce fundamentally innovative outcomes. Others have argued that the search for an external network is needed to connect innovative strategies (Li & Atuahene-Gima, 2001) and ongoing interactions between knowledge inputs and a second-order learning process. Using a successful second-order learning process in the past will increase the probability that an organization will rely on that in the future. Thus, it is second-order learning

process rather than first-order that can reshape the relationship between innovation inputs and outputs.

Organizations pursuing exploratory R&D inputs are likely to produce exploratory outputs because of distant search routines in evolutionary economics as explained in Hypothesis 1. Organizational inertia may prevent an organization from deviating from accustomed routines (Levitt & March, 1988). When second-order learning processes are combined, organizations may expect considerable changes such as reorienting their routines, approaching goals in a different way, and modifying policies (Lant & Mezias, 1992; Tushman & Romannelli, 1985). Even when R&D inputs are exploitative, a change in intention and environmental fluctuation can entirely reshape final outputs. Strategic reorientation and environmental change cause organizational members to reconsider their existing approaches and procedures. Thus, second-order learning processes tend to reshape exploitative inputs into exploratory outputs, and intensify the positive association between exploratory innovation inputs and outputs. Therefore, we predict the following:

Hypothesis 2 Given innovation inputs, second-order learning processes significantly moderate the relationship between innovation inputs and outputs.

Hypothesis 2a Second-order learning processes positively moderate the relationship between exploratory innovation inputs and exploratory innovation outputs.

Hypothesis 2b When a second-order learning process is applied, exploitative innovation inputs may lead to exploratory innovation outputs.

Methods

Sample and data

We draw our sample from the top 100 Korean companies (in terms of annual sales) included in the Korea Composite Stock Price Index (KOSPI). Since the Asian financial crisis of 1997, Korea has fostered a fairly successful economy as an emerging market with intense environmental changes and strategic reorientations, a context which may be sufficient for investigating the impact of second-order learning (Kim, Bae, & Garry, 2012). The companies in our study also provide a rare empirical opportunity to examine the relationship between innovation inputs and outputs in an emerging market context. We chose them based on knowledge seeking behaviors critical for sustaining their survival, because their historical evolution is relatively easy to track, and because they are exceptionally active in terms of capital expenditure in both exploration and exploitation innovation inputs.

After excluding firms that lacked detailed R&D activities, one of the key inputs for the innovative output, in their corporate publications, our base sample for this study was 93 companies. For data gathering we relied on annual reports obtained from the Financial Supervisory Service DART (Data Analysis, Retrieval and Transfer) system. We collected the 11-year panel data of R&D inputs, outputs, and second-order learning processes adopted by these firms from 1997 to 2007.

Dependent variable

Exploratory output Following studies that relied on change in sales amounts (Bierly & Daly, 2007; Burgelman, 2002; Cao, Gedajlovic, & Zhang, 2009; He & Wong, 2004), our dependent variable, exploratory output, was measured using changes in variance of sales composition not likely to be the result of existing corporate activities, but from search and investment activities in different fields. In terms of learning process, this outcome does not overlap with input and final outcomes of corporate R&D activities and yields relatively high clarity. We measured the change in sales composition during the first three years after initial R&D investment. Following previous research (Artz, Norman, Hatfield, & Cardinal, 2010; Katila & Ahuja, 2002), we lagged the three years between R&D investments and subsequent changes in sales compositions. We collected the data about sales composition from annual reports. Our focus of analysis was about incremental changes due to new products or technologies.

Independent variables

Exploitative R&D input and exploratory R&D input The Korean Generally Accepted Accounting Principles (K-GAAP) regulate how expenses on R&D may be classified, as either research expenses or ordinary development expenses. We follow the K-GAAP criteria to distinguish research expenses from ordinary development expenses. These classification criteria list examples of what may be classified as research expenses (i.e., activities to acquire new knowledge, searching for research results, and improvements in materials, equipment, product, process, system, service, etc.). Examples of development expense activities include designing, manufacturing, and examining activities of prototypes prior to usage and of the finished final item for which economic profit will be generated once the development process is completed.

In order to measure exploratory R&D input, we chose change in research expense. These were measured as a year-on-year increase in research expense taken from annual reports. We log-transformed the values to control for possible skewed distribution of our sample. We also measured exploitative R&D inputs with changes in development expenses as a year-on-year increase in development expense from the annual reports. This was also log-transformed.

Second-order learning Strategic reorientation is a discontinuous and simultaneous transition of organizational strategy, structure, power distribution, and control practice (Tushman & Romanelli, 1985). Previous studies of the second-order learning process used the "reorientation of organizational strategy" concept as an empirical variable (Lant, Milliken, & Batra, 1992; Virany et al., 1992). This study used three measures of second-order learning: *CEO turnover*, *Board turnover*, and *R&D alliances*. CEO turnover is recognized as a new learning activity inside organizations, reported to influence the reorientation of corporate strategies and performance (Lant et al., 1992; Virany et al., 1992). When a CEO is replaced, change occurs in the overall decision making system and reorientation takes place in various areas of an organization. We measure CEO turnover as the number of CEO changes occurring within the last three years since R&D investment.

Board member turnover is an organizational mechanism that can alter the inner and outer environment. Thamhain (2003) argued that organizational components such as leadership and people play important roles in R&D team performance. A new board member may cause reorientation of organizational strategy and possible shifts in power structure and control system. Changes in board members can also bring about new learning effects and influence organizational performances (Lant et al., 1992; Virany et al., 1992). To test this, we counted director replacement compared to the previous year.

Many companies enter into R&D alliances agreements in pursuit of new knowledge (Sampson, 2007). R&D alliances represent corporate efforts to acquire knowledge and the type of alliance reorients corporate strategies (Lavie & Rosenkopf, 2006). In the R&D process, strategic alliances manage innovation strategy and final output (Li & Atuahene-Gima, 2001). Therefore, we counted new alliance agreements in annual reports.

Control variables

We included several control variables that could affect the results but were not our main theoretical scope. *Sales growth rate* measured the rate of increase in sales amount. Sales growth rate includes all increased performance that occurs from activities including R&D inputs and other marketing activities. To control these, we included sales growth rate as a control variable. We also included *Firm size* and *Firm age* to minimize their influence on the size of R&D inputs. Firm size was defined as the logarithm of total assets, and firm age was measured by the log-transformed number of years since incorporation. We included an *Industry dummy* to control for the effect of industry on R&D and capital investment.

Model specifications

The strength of panel analysis lies in its ability to observe both time series and cross-sectional changes and capture both observable and unobservable effects of the independent variable on the dependent variable (Baltagi, 2001; Hsiao, 2003). Following Breusch and Pagan (1980), a Lagrange multiplier test was conducted to check the suitability of samples for panel analysis. The result of the Lagrange multiplier test showed a result lower than the p-value of .00, rejecting the null hypothesis at the .1 % level of significance. These samples are more suitable for a random effects panel analysis than pooled ordinary least squares (OLS) which assumes observation values of a firm from different time points to be a separate datum (Greene & Zhang, 2003). In order to conduct a sound panel analysis, two preconditions about variances and covariance of error terms must be met: (1) they should not be auto-correlated and (2) the error terms of the observations should be homoskedastic (Bergh & Holbein, 1997). The Wooldridge (2002) test rejected the null hypothesis, stating that first-order autocorrelation does not exist within errors of panel linear regression model, so we took the panel-specific autocorrelation condition to assume that each panel has autocorrelation. Since our dataset was likely to be biased due to heteroskedasticity, panel feasible generalized least squares (FGLS) was implemented in the analysis (Greene & Zhang, 2003).

Results

Table 2 illustrates the descriptive statistics and correlations between variables. The correlation table indicates that correlations between major variables are not high. Before conducting the main analysis, we examine the multicollinearity assumption. Variance inflation factors (VIFs) indicate no serious multicollinearity problems. The largest VIF of the variable is 3.81, indicating that all variables recorded VIFs less than the universal standard of multicollinearity of 10.

Table 3 provides the results of random-effects FGLS regression analysis which measured changes in research expenses and in development expenses as independent variables. The Wald chi-square statistics in this table show that all models are highly significant ($p < .01$) and the addition of our key variables improved model fit. Model 1 is the base model including only the control variables, and Model 2 is the regression model to test Hypothesis 1. Models 3, 4, and 5 are models with various interaction terms with exploratory and exploitative innovation inputs to test Hypothesis 2.

Before verifying the hypotheses, the base model shows that the dependent variable is significantly influenced by firm size. In Hypothesis 1a, we predicted a positive relationship between exploratory innovation inputs and exploratory innovation outputs. From Model 2 in Table 3, we see that the coefficient for changes in research expenses is negative and significant ($p < .01$). Contrary to our argument, this result indicates that exploratory innovation inputs are negatively associated with exploratory innovation outputs. Hypothesis 1a is not supported. In Hypothesis 1b, we predicted a negative relationship between exploitative innovation inputs and exploratory innovation outputs. From Model 2 in Table 3, we see that the coefficient for change in development expenses is negative and significant ($p < .01$). Hypothesis 1b is strongly supported.

In Hypothesis 2a, we predicted a positive interaction effect of second-order learning process with changes in research expenses on exploratory innovation outputs. It is verified in Models 3 to 5. Model 3 measured second-order learning with CEO turnover. The interaction effect is supported ($p < .01$). Model 4 measured board turnover as second-order learning. The interaction effect shows a significant result ($p < .1$). Model 5 gave the number of R&D alliances for external knowledge sourcing as a second-order learning process. We see that the coefficient for the interaction term is not significant. Of the three constructs designed to measure second-order learning, CEO turnover and board turnover are supported. In Hypothesis 2b, we predicted a positive interaction effect of second-order learning process with changes in development expenses on the exploratory innovation outputs. It is also verified from Models 3 to 5. Model 3 measured second-order learning with CEO turnover. The interaction effect is supported ($p < .05$). Model 4 measured board turnover as second-order learning. The interaction effect shows a significant result ($p < .05$). Model 5 observed number of R&D alliances. This model shows that the coefficient for interaction term is not significant.

We also ran additional tests to check the robustness of our results. First we measured exploratory innovation inputs as changes in commissioned research contracts for more focused exploratory activities. We reestimated our models with the same analyses. The results for all analyses were qualitatively similar to the reported results (available from the authors). Second, though we focused on the 100 top Korean companies, we repeated the same analyses using selected sets of data from companies who had converted their main business in the past three decades.

Table 2 Descriptive statistics and correlations

	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Changes in sales composition	.033	.129	1.000								
2. Changes in research expenses	1.439	3.110	−.048	1.000							
3. Changes in development expenses	5.284	3.856	−.113**	−.161***	1.000						
4. CEO turnover	.002	.826	−.040	.015	−.006	1.000					
5. Board turnover	−1.403	13.189	−.001	−.062	−.040	−.027	1.000				
6. Number of R&D alliance	1.634	4.224	−.042	.234***	.232***	−.024	−.025	1.000			
7. Firm size	14.523	1.282	−.049	.232***	.336***	.107***	−.086**	.267***	1.000		
8. Firm age	3.273	.882	−.044	.106**	−.063	.028	−.045	−.084**	.159***	1.000	
9. Sales growth rate	93.104	1814.075	−.008	−.025	.031	.004	.000	−.017	−.013	.151***	1.000

* $p < .10$; ** $p < .05$; *** $p < .01$

Table 3 FGLS estimates of regression on exploratory outputs

	Model 1	Model 2	Model 3	Model 4	Model 5
Changes in research expenses		−.00090***	−.00121***	−.01133***	−.00096***
		(.00028)	(.00028)	(.00028)	(.00032)
Changes in development expenses		−.00080***	−.00123***	−.00126**	−.00104***
		(.00025)	(.00026)	(.00023)	(.00027)
CEO turnover			−.00731***		
			(.00193)		
Changes in research expenses × CEO turnover			.00062**		
			(.00029)		
Changes in development expenses × CEO Turnover			.00112***		
			(.00030)		
Board turnover				−.00032**	
				(.00017)	
Changes in research expenses × Board turnover				.00002**	
				(.00001)	
Changes in development expense × Board turnover				.00003*	
				(.00002)	
Number of R&D alliance					.00054
					(.00072)
Changes in research expenses × Number of R&D alliance					.00008
					(.00007)
Changes in development expenses × Number of R&D alliance					−.00062
					(.00075)
Firm size	−.00130	.00267*	.00316**	.00307***	.00252**
	(.00080)	(.00118)	(.00121)	(.00112)	(.00127)
Firm age	−.00699***	−.01110***	−.00747***	−.01086***	−.01070***
	(.00238)	(.00283)	(.00233)	(.00278)	(.00305)
Sales growth rate	−.000000	−.00003	−.00004	−.00002	−.00004
	(.00000)	(.00003)	(.00003)	(.00003)	(.00003)
Industry dummies	Included	Included	Included	Included	Included
Constant	.04170***	.00286	−.01410	−.00331	−.74301***
	(.01040)	(.01452)	(.01513)	(.01418)	(.23122)
Wald Chi-Square	69.43***	54.86***	69.01***	146.97***	57.01***
Prob. > Chi-Square	.00000	.00000	.00000	.00000	.00000

* $p < .10$; ** $p < .05$; *** $p < .01$

Corporate transformation may be regarded as the successful accomplishment of organizational innovation (Burgelman, 1996). About 30 companies fit this category including LG Chemicals, Samsung SDI, and Hyundai Heavy Industries. Even given this sample, Hypothesis 1a was rejected summarily. This shows the moderating effect of second-order learning obtains even for companies that experience dramatic changes in sales composition.

Discussion

Contributions

In applying knowledge-seeking activities of exploration and exploitation to corporate R&D activities, this study empirically suggests how exploratory or exploitative R&D inputs are linked to exploratory innovation outputs. By applying a second-order learning process (Lant & Mezias, 1992), this study attempts to reinvestigate the changes in overall R&D processes. Empirical results showed that exploitative R&D inputs were negatively related to exploratory output in the absence of any organizational learning process. Contrary to our prediction, exploratory R&D inputs were negatively associated with exploratory R&D output. Though previous studies have argued that exploratory search activities and routines are highly correlated with exploratory output (Lavie & Rosenkopf, 2006; Rosenkopf & Nerkar, 2001), due to inertia and existing routines, Korean firms have failed to align their internal learning processes in order to motivate organizational members to find new knowledge across organizational boundaries. Our results showed that internal mechanisms like an organizational learning process are an important factor in increasing exploratory output regardless of innovation input type.

We found that the interaction effects between second-order learning process and exploratory and exploitative innovation inputs had a positive association with exploratory outputs. For the impact of second-order processes, there were meaningful variances in statistical significance. CEO and board turnover, which are strongly correlated with direct discontinuous and simultaneous transitions of organizational strategy, moderated the impact of exploratory and exploitative innovation inputs on exploratory innovation outputs. On the other hand, the second-order learning process measured by R&D alliances did not show significant interaction effects. Previous studies have reported that R&D alliances with new partners can lead to the subsequent development of innovative technologies and bring exploratory innovation outputs (Koza & Lewin, 1998). The fact that we could not find any significant impact of alliances may imply that Korean companies classify simple technology licensing agreements as technological alliances in their annual reports. We also found that in Korean companies R&D alliances were not sufficient to change the relationship between innovation input and output. Thus, we empirically suggest that second-order learning can reshape the relationship between innovation inputs and exploratory innovation outputs.

Theoretical implications

This study offers several theoretical implications including new guidelines for future research. Academic scholars need to focus the sequential linkage between R&D

activities and innovation performance in terms of organizational learning, which include the roles played by internal learning mechanisms and the characteristics of innovation input. Types of innovation input may determine the potential substance of future outputs from the organizational learning process point of view. Moreover, we further suggest that individual organizations develop a transformational capability to convert given inputs into meaningful innovation outputs. Such capabilities are often related to internal learning mechanisms such as networks of collaborations, strategic reorientation, M&As, and CEO successions. This study provides a way to explain the mixed empirical results of the relationship between exploration/exploitation-type innovation inputs and innovation outputs. Considering the significant role played by the internal learning process, individual organizations could turn the same inputs into significantly different outputs by employing various alternatives (Chiu, Huang, & Chen, 2012; Christensen, 2006). Finally, the type of second-order learning process emphasizing strategic reorientation may determine the type of output produced. In particular, internal changes such as CEO and board turnover proved to be a more critical factor in producing exploratory innovation outputs rather than R&D alliances.

Practical implications

This paper contributes to practice by showing implications for firms conducting R&D activities. It is critical to understand how input itself does not produce the same kind of successful innovation output. Managers need to recognize that aggressive investment in innovation inputs can sometimes exacerbate innovation outputs when they do not apply an optimal internal learning process. Specifically, to increase entirely new innovations and exploratory outputs, they must secure the right innovation inputs and integrate efficient knowledge transformation mechanisms. While previous studies have highlighted the effectiveness of inter-firm alliances, our study does not confirm the utility of alliances for dramatic innovation but rather suggests that CEO leadership is one of the most critical factors in determining innovation output. When CEO leadership is combined with different types of innovation input, the CEO is more influential than either input. These findings may be specific only to Korea, since our research took place during a period well-known for the critical impact of transformative leadership on most Korean firms (Froese, 2013).

Limitations and future research

Our study is not, however, free of limitations. We did not integrate the impact of first-order learning, which may be more effective than second-order learning in different contexts. For example, when an industry is old, mature, and technologically stable, the first-order learning process may bring ready-made knowledge and innovations. Future studies may investigate conditions where first- or second-order learning processes are more effective in terms of creating successful innovations. Second, our study did not consider how dramatic changes in the competitive environment can alter knowledge seeking behavior and internal learning processes. Previous studies have reported that financial crisis or stock market bubbles fundamentally change existing relationships between corporate strategies and financial outcomes (Park & Mezias, 2005). To better understand the dynamic effects of ever-changing environments, studies may wish to

replicate ours in the context of crises or dramatic changes in government regulations (Zhu, Wittmann, & Peng, 2012). Third, our research investigated only large Korean firms from 1997 to 2007. As such, these findings may be limited in terms of generalizability across corporate size, level of technology development, country, and economy. Future studies could easily replicate our analyses in terms of emerging markets like India, China, and Brazil. These could be extended by analyzing the same question in advanced economies. Fourth, our study relied only on quantitative analysis methods. However, the sequential process of organizational knowledge creation may be better understood using qualitative approaches such as focus group interviews, in-depth case studies, and field analyses. These studies could fruitfully triangulate their findings with previous statistical findings. Finally, future studies may wish to extend our research question by integrating other strategic management issues such as corporate strategic orientations, market-seeking and technology-seeking activities, organizational culture, characteristics of executive members, and hierarchical structures.

Conclusion

In seeking an explanation for the mixed results of exploration and exploitation studies following March's (1991) research, this study presents the need for understanding exploration and exploitation in terms of learning processes. Based on the organizational learning view, this study analyzed R&D activities as a sequential process of making innovation inputs, applying internal learning process, and creating innovation outputs. Most previous studies were based on an implicit assumption that a certain form of knowledge creation inputs, whether exploration or exploitation, may lead to the same form of knowledge creation outputs. However, knowledge-seeking activities do not always produce successful innovation outputs, and the relationship between R&D investments and performance can be uncertain and demanding. In applying knowledge-seeking activities of exploration and exploitation to corporate R&D activities, this study investigates how the second-order learning process moderates the relationship between innovation performances. We investigate the second-order learning process of the top 100 Korean firms from 1997 to 2007 by capturing CEO turnovers, board turnover, and R&D alliances. Our empirical results show that while innovation inputs are not related to exploratory outputs, the second-order learning process reshapes the relationship between both exploration/exploitation type innovation inputs and exploratory innovation outputs. This paper suggests the new focus of organizational learning process can refine current innovation literature.

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Hyojung Kim (PhD, Seoul National University) is a professor of International Trade and Business at Sangmyung University. Her research interests focus on organizational learning, exploration/exploitation, and foreign direct investment. Her research has appeared in the *Asian Case Research Journal*, *Journal of Strategic Management*, *Korea Business Review*, and *International Business Review.*

Namgyoo K. Park (PhD, New York University) is a professor of Strategy and International Business at Seoul National University. His research investigates knowledge creation, creativity management, firm boundary expansion, and firm performance in both domestic and global settings. His research has appeared in the *Strategic Management Journal*, *Journal of Management*, *Transportation Research*, *Asia Pacific Journal of Management*, *Industry and Innovation*, *Journal of Air Transport Management*, and *International Journal of E-business Strategy.*

Jeonghwan Lee (PhD, Seoul National University) is a professor of Strategy and International Business at Myongji University. His research interests focus on innovation, knowledge management, M&As, and foreign direct investment. His research has appeared in the *Industry and Innovation*, *Asian Case Research Journal*, *Journal of Strategic Management*, and *Korea Business Review.*