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Firms' openness in specialized search and digital innovation among process-oriented mining enterprises: A moderated mediation model

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1. Introduction

China's mining enterprises are constantly under pressure to improve their production processes and operational resilience. "Sweating" existing assets is one way these enterprises meet the changing market demands and cope with radical changes in input and output requirements. But this strategy has its limitations (Deloitte, 2019). Digital process innovation (DPI) can provide a more sensible path. In a nutshell, DPI refers to "a process that is perceived as new, requires some significant changes on the part of adopters, and is especially embodied in or enabled by digital technologies" (Fichman et al., 2014; Nambisan et al., 2017). Developing DPI not only helps mining companies to increase productivity and efficiency but also contributes to better health and safety conditions in mining environments, hence, gives the firms a sustainable competitive advantage (Gruenhagen and Parker, 2020).

DPI naturally involves very advanced digital technologies (Nambisan et al., 2017; Kohil and Melville, 2018). The required knowledge and skills for the designing and implementation of digital technologies often lie outside the core competencies of process-oriented mining enterprises (Di Vaio et al., 2021; Kamalaldin et al., 2021). The remedy would be for these enterprises to be open to external knowledge and have a search strategy to acquire useful external solutions and technologies. The knowledge can then be integrated into their own process innovation.

Only recently the literature on open innovation has focused on process innovation (e.g., Aliasghar et al., 2019). There has been little attention to the proper strategy for search and internalizing the knowledge, less so for process-oriented industries. For example, previous studies have highlighted that external search plays important role in developing conventional process innovation (Gao and Ding, 2020; Aliasghar et al., 2019). However, some scholars suggest that the mechanics of conventional process innovation may not be directly applicable to digital process innovation due to the fundamental differences between these two types of innovation (Chirumalla, 2021; Kamalaldin et al., 2021 Nambisan et al., 2017). Furthermore, while existing works have highlighted that a firm can be ambidextrous – pursue both exploitative and exploratory innovations simultaneously–they still focus on exploitative process innovation work (Lee et al., 2018), neglecting the potential multifaceted characteristics of process innovation (Chirumalla, 2021; He and Wong, 2004). Moreover, the existing literature has mainly focused on activities related to process innovation within manufacturing firms. In mining, on the other hand, products are often undifferentiated (e.g., raw coal, oil, gas), hence, there is very little space for product innovation (Radnejad and Vredenburg, 2019). For these firms, it is more practical to separate product innovation from process innovation. Thus, a focus on process innovation is more important for a process-oriented industry, such as mining, than for manufacturing.

The literature on open innovation has also highlighted the role of search breadth and its depth for innovative activities (e.g., Flor et al.,

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2018; Terjesen and Patel, 2017; Segarra-Ciprés and Bou-Llusar, 2018). These works, however, do not offer deep attention to the ways in which features of firm's openness in external search strategies-specifically, its actual search direction-may facilitate innovation activities (Kohler et al., 2012; Sofka and Grimpe, 2010). To fill these gaps in the literature, we first extend the existing research by examining the influence of strategies a firm adopts to conduct specialized search on ambidextrous DPI (exploitative versus exploratory) in process-oriented mining enterprises. In particular, we consider and compare two strategies: value chain partner-driven search and science driven search.

The premise is that external knowledge is 'out there', ready to be utilized by enterprises (Flor et al., 2018). Nevertheless, the flow of external valuable knowledge into enterprises is not an easy or automatic process. It is essential for mining firms to have certain capabilities that allow them to acquire, assimilate, and exploit external core knowledge. This capacity is often defined as "absorptive capacity" (AC) (Cohen and Levinthal, 1990; Zahra and George, 2002). Recently, scholars have investigated the mediating role of this factor and its influence on firm performance, product innovation or business model innovation (e.g., Ferreras-Méndez et al., 2015; Flor et al., 2018; Miroshnychenko et al., 2020). However, literature has paid little attention to process innovation, especially regarding DPI. Therefore, the second objective of this study is to investigate whether AC influences the relationship between firm's specialized search and ambidextrous DPI in any way.

Organizational innovativeness (OI) reflects organization's willingness and enthusiasm to carry out innovation activities (Hurley and Hult, 1998; Hult et al., 2004). Most studies have emphasized the importance of OI as an enabling factor that stimulates organizational learning and accelerates the absorption of new knowledge (Rhee et al., 2010; Kim et al., 2018; Gretsch et al., 2019). However, from the viewpoint of digital innovation, to our best knowledge, this study is one of the first that investigates the influence of OI on ambidextrous DPI. By facilitating knowledge absorption and learning, OI may also influence DPI. This study thus explores whether OI has any role in linking the mining firm's openness in specialized search, AC, and ambidextrous DPI.

This study empirically tests a moderated mediation model, which includes indicators for a firm's openness in specialized search, AC, OI and ambidextrous DPI. According to the theory, two types of ambidextrous DPI are considered, namely exploitative DPI and exploratory DPI. The nexus between firm's openness in specialized search and ambidextrous DPI is discussed. We find that AC plays an important and mediating role in the above relationship. We also show that this mediating role of AC is stronger when OI is higher in this process.

The paper is organized as follows. In the next section, we construct our theoretical model and establish a few hypotheses based on the model. We, then, present the research design. Using structural equation models, we test the hypotheses. Finally, we list the research findings, and offer a few theoretical and managerial implications and will also discuss limitations.

2. Theoretical background and hypotheses development

2.1. Conceptual background

2.1.1. Digital process innovation in mining enterprises

According to the literature, process innovation can be categorized into two main types: organizational and technological (Edquist et al., 2001). Organizational process innovation focuses on improvements in organizational strategy and structure, administrative processes, and management processes (Armbruster et al., 2008; Edquist et al., 2001). Technological process innovation refers to the introduction of new components, such as new technologies and production methods, into an organization's production processes that will reconfigure resources and capabilities, improve their efficiency, reduce environmental impacts and lower costs (Brem et al., 2016). Most Chinese mining enterprises have more focus on the development of technological process innovation rather than on the organizational type. Such approach is most probably caused by the long-term conservative culture that reigns in these enterprises. For that reason, this paper dedicates its efforts to studying technological process innovation.

Digital technologies are a major driving force behind the process innovation. In view of the current literature on digital innovation (Yoo et al., 2010; Nambisan et al., 2017; Holmström, 2018), we consider digital tools as facilitating and enabling process innovation. Our approach follows that of Nambisan et al. (2017), where he describes digital process innovation as "a range of innovation outcomes, such as new products, services, and process; as long as these outcomes are made possible through the use of digital technologies, though the outcomes themselves do not need to be digital". For instance, many mining firms from Shanxi province – a major coal producing province in China – are now investing heavily in digitalization to improve their production processes through innovative digital technologies such as robotics, autonomous solutions and multifunctional digital security systems. The goal is to enable new or significantly improved production or delivery methods. Some have even taken steps towards constructing digital mines.

Although these examples are promising, this area is still an emerging field compared to the conventional process innovation. Insights into the conceptual and empirical aspects of the practice remain rudimentary. Some scholars argue that the term "use" of digital technologies is overly crude in the existing context and call for "increase the granularity of how one conceptualizes 'use'" in order to improve one's understanding of the development of DPI (Verstegen et al., 2019; Monteiro, 2018). Building on previous literature on innovation ambidexterity, we employ the classical ambidextrous analysis as a theoretical lens to gain more insights into the development of exploitative and exploratory DPI. Specifically, we define exploitative DPI as an innovative activity in which mining enterprises improve and modify their existing production and operations via integrating digital tools into their current technology. This concept emphasizes the development of a digitally based process in mining enterprises. One such example is a real-time data analysis-based solution for existing production processes.

We define exploratory DPI as an innovative activity in which mining enterprises focus on breaking through existing technological and process barriers to develop new production systems or processes that utilize digital technologies. Exploratory DPI focuses on the digitalization of the innovation process itself (Robertson et al., 2012; Fichman and Santos, 2014; Nambisan et al., 2017; Kohil and Melville, 2018; Gruenhagen and Parker, 2020). Given the complexity of developing DPI and the lack of internal knowledge, it is challenging for mining firms to acquire the necessary expertise and skills in order to design the digital infrastructure on their own (Hohberger, 2014; Kamalaldin et al., 2021). Thus, external sources of knowledge are gaining importance for mining firms (Laursen and Salter, 2006; Sofka and Grimpe, 2010).

2.1.2. Firm's openness in specialized search

Laursen and Salter (2006) first introduce the core concepts of search breadth and search depth in a quantitative context in their seminal paper. They, further, show that the breadth and depth are two components of the openness of individual firms' external search strategies. Later works have used these two indicators to measure the firm's openness in external search strategies (e.g., Ferreras-Mendez et al., 2015; Segarra-Ciprés and Bou-Llusar, 2018; Flor et al., 2018). However, more recent studies have noted that actual search direction is critical for innovation activities, because different sources of external knowledge may be heterogeneous (Sofka and Grimpe, 2010). Base on this view, Sofka and Grimpe (2010) develop a type of specialized search strategy, which they label as Value Chain Partner-driven Search (VCPS) and Science-driven Search (SCIS). VCPS refers to a firm's search for external sources of knowledge that mainly lie with suppliers, competitors, industry associations or consulting firms. SCIS refers to search for specialized knowledge held by universities, research organizations,

professional conferences, forums, and government research agencies. There has been evidence that firms don't randomly select external knowledge sources but choose them strategically for innovation (Sofka and Grimpe, 2010; Kohler et al., 2012; Un and Asakawa, 2015). For instance, knowledge searched from universities and research institutions may be distant and have more theoretical elements, while knowledge searched from ICT suppliers is closer and more conforming to the knowledge held by the firm (Kohler et al., 2012; Kohil and Melville, 2018). Thus, it is particularly important for mining companies to know where to search for digital process innovation.

2.1.3. Absorptive capacity

AC is defined in various forms (for a review, see Roberts et al., 2012). It is generally conceptualized as the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends (Cohen and Levinthal, 1990). A firm with absorptive capacity is better at assessing stimuli from the external environment, identifying new external knowledge, and assimilating it with internally held knowledge (Zahra and George, 2002; Lane et al., 2006). In our study, we mainly follow Zahra and George (2002) and Lane et al. (2006) in defining AC. They refer to AC as a knowledge management process: a firm's capability to combine new knowledge gained from external partners with existing knowledge base and employ it to generate new processes. In the context of digital innovation, mining firms may require to build up these capabilities before designing their DPI strategies.

2.1.4. Organizational innovativeness

OI refers to an entity's notion of openness to new ideas, novelty, experimentation, and creative processes (Hurley and Hult, 1998). Briefly speaking, it emphasizes the organizational characteristics instead of behavioral results. Importantly, it reflects the innovation-centric atmosphere in the organization and that the resulting innovations are regular and repeated (Hult and Hurley, 2004). Relevant works have found that organizations with higher levels of innovativeness are more likely to embrace innovative technologies. In the context of openness for DPI, innovativeness may create an atmosphere that accelerates the process of knowledge absorption and, consequently, facilitates the adoption and development of digital technologies. Hence, OI is a potential driver of DPI in firms. For that reason, we use OI as an enabling factor.

2.2. Research model

Our conceptual model builds on innovation management literature which posits that the development of process innovation requires valuable external knowledge. It also relies on absorptive skills to process and makes use of that knowledge, so that innovations can be made and implemented successfully. This conceptual model is shown in Fig. 1. The model has its basis in the earlier theories of external knowledge search strategies, absorptive capacity and process innovation (Ferreras-Mendez et al., 2015, 2016; Sofka and Grimpe, 2010; Aliasghar et al., 2019). This class of models maintains that leveraging external knowledge is important for a firm's innovation and performance, and that the absorptive capacity mediates the influence of external knowledge search strategies on innovation.

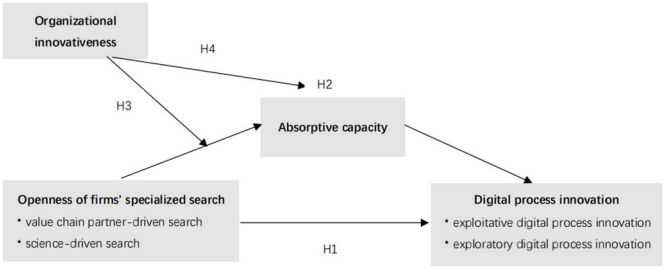

Fig. 1. Proposed research model.

Our model builds on these basic principles but also extends them in a few important aspects. Fig. 1 introduces organizational innovativeness as an important force when the firm is open to external search. Organizational innovativeness can accelerate innovation through increasing the external focus and facilitating internal integration (Acar, 2012; Gabler et al., 2015; lin et al., 2020). As such, the extent to which external knowledge contributes to absorption processes could be influenced by organizational innovativeness of the firm.

Our model differs from the existing models in two ways. First, previous research has mainly focused on exploitative or incremental process innovation, ignoring the exploratory features brought by digital technologies (e.g., Robertson et al., 2012; Un and Asakawa, 2015; Stadler, 2011; Terjesen and Patel, 2017; Aliasghar et al., 2019). In contrast, we use an ambidextrous notion of innovation that offers more insight into the development of process innovation. Second, existing models show the influence of search breadth and its depth on process innovation, but do not investigate if there are any alternative search strategies, such as specialized search, that are more effective than the default method. In view of these shortcomings, we present a step-by-step argument below to incorporate the new elements.

2.3. Firm's openness in specialized search and ambidextrous DPI

In this section, we will explore the influence of firm's openness in specialized search on exploitative and exploratory DPI, respectively.

We conjecture that the strategy used to acquire specialized knowledge makes a difference in the development of exploitative DPI. The use of external knowledge and digital technologies to incrementally improve existing operational processes are the important characteristics of exploitative DPI. Compared to exploratory DPI, exploitative digital innovations for coal production processes require only minor changes as they already fit into the normal operation of the firm and allow for the application of prior experience (Linder and Sperber, 2019; Nambisan et al., 2017; Aliasghar et al., 2019). In this context, mining firms could be depending on a specialized search strategy that seeks knowledge that is closer to their own stock of knowledge in order to accelerate the use of that knowledge and the development of exploitative DPI. In terms of VCPS, suppliers – in particular, suppliers of intelligent industrial products – often share a close inter-organizational relationship with the firm's business unit and their knowledge is close in context to the knowledge held by the mining companies. Knowledge provided by these suppliers not only helps mining companies to be more targeted in identifying digital issues in their operation of mining equipment, but also provides information that is especially synergistic with the mining firm's own operation (Ferreras-Mendez et al., 2016; Sofka and Grimpe, 2010). For instance, suppliers of "intelligent" industrial product can provide businesses with digital practices that are more operational and conducive to the developing of exploitative DPI. Competitors also share similar contextual knowledge useful to firms in the same industry (Dussauge et al., 2000). Best practices developed and held by competitors in mining industry can be quite relevant and potentially useful to the other mining companies. Industry associations also hold similar contextual knowledge to firms in a certain industry – here mining – where knowledge provided by these institutions is typically actionable (Un and Asakawa, 2015). Specialized search of knowledge held by these associates can be helpful in developing exploitative DPI. Prior studies suggest that searching knowledge from consulting firms is also an important avenue for enterprises to develop innovation (Laursen and Salter, 2014). These firms may also help mining companies to diagnose problems in process management and develop exploitative DPI solutions to address them. In terms of SCIS, searching knowledge from academic institutions are valuable avenue for mining firms and tend to provide systematic, theoretical and untapped knowledge to outsiders, some of which may even be tacit and highly innovative (Cohen et al., 2002; Link

et al., 2006; Sofka and Grimpe, 2010; Un and Asakawa, 2015). Nevertheless, while SCIS may be useful in all these ways for mining firms, the context of the knowledge itself may be far from what mining companies understand and apply. In this case, substantial investments are typically required to develop the final outputs (Link et al., 2006; Kohler et al., 2012; Un and Asakawa, 2015). Hence, we expect that when the acquired knowledge is close in context to the mining firm's own stock of knowledge, the firm is likely to develop exploitative DPI by directly putting the external knowledge into use and into digital innovations. Based on this argument, we propose the following Hypothesis:

Hypothesis 1a. . Value chain partner-driven search has a more positive effect on development of exploitative DPI than science-driven search.

On the other hand, the new principles of coal production, the significant adaptation of digital operating procedures and investments in new digital equipment are some of the important features of exploratory DPI (Linder and Sperber, 2019). In contrast to exploitative DPI, exploratory DPI requires a complete rethinking of the actual processes and involves highly novel technological knowledge (Linder and Sperber, 2019; Nambisan et al., 2017; Aliasghar et al., 2019). In this context, a VCPS gives mining firms access to a wide variety of technological knowledge that enriches the firm's own pool of knowledge and thus may improve the firm's chances of developing exploratory DPI (Sofka and Grimpe, 2010).

In contrast to a VCPS, a SCIS not only gives firms access to especially novel, systematic and tacit knowledge, with the potential to assist in the development of exploratory DPI, but also allows mining firms to develop a more profound understanding of the logic behind exploratory DPI. Moreover, despite the possibility of specialized knowledge (e.g. from academic institutions) being too different from firm's knowledge and being too theoretical (Un and Asakawa, 2015), it is still easier for the firm to rethink the existing production process from beginning to end based on the specialized knowledge in a completely exploratory and innovative way. Based on these points, we propose the following Hypothesis:

Hypothesis 1b. . Science-driven search is more effective in the development of exploratory DPI than value chain partner-driven search.

2.4. The mediating role of absorptive capacity

The AC emphasizes processes, routines and the structure of organization that allow firms to identify, assimilate, transform and exploit external knowledge (Zahra and George, 2002). Previous studies have shown that a firm's openness to external search exposes the firm to various sources of ideas that will expand its stock of knowledge. The firm will, then, have more capabilities and cognitive abilities to identify, transform and exploit valuable, tacit knowledge (e.g., Ferreras-Mendez et al., 2016; Flor et al., 2018; Aliasghar et al., 2019; Gao and Ding, 2020).

Within our context, coal companies use digital technologies to develop DPI, often in ways that go beyond traditional capabilities and knowledge. As a result, maintaining openness to external knowledge can offer access to heterogeneous sources of knowledge, thus enhancing the firm's capacity to acquire and assimilate potentially valuable knowledge (West and Bogers, 2014). Furthermore, openness to specialized knowledge can assist in establishing deep relationships with value-chain partners and universities or research organizations that allows these firms to increase the chance of transforming and exploiting the new knowledge in conjunction with the firm's existing knowledge (Ferreras-Mendez et al., 2016). Hence, firm's openness in specialized search may contribute to help the mining firms to improve their absorptive capability.

Previous research has shown that absorptive capacity can facilitate product, service and conventional process innovation and suggests that the higher a firm's absorptive capacity, the greater its innovation and performance (Ferreras-Méndez et al., 2015; Flor et al., 2018). For example, Ferreras-Mendez et al. (2015) argued that acquiring, assimilating, transforming and exploiting knowledge enables firms to keep track of market changes and expand their capabilities more effectively, further developing innovation-related activities. Aliasghar et al. (2019) argue that absorptive capacity enables firms to introduce or create novel knowledge and technology elements into production operations for process improvement. We also suggest that AC has a positive mediating effect in the relationship between openness of firms' external search and ambidextrous DPI. Based on this argument, we propose the following hypotheses:

Hypothesis 2. AC mediates the relationship between firm's openness in specialized search and ambidextrous DPI.

2.5. The enabling role of organizational innovativeness

We also investigate the contingent role of organizational innovativeness as an enabler of the association between openness of firms' specialized search and AC.

Relevant studies have found that organizational innovativeness has a positive effect on a firm's technology acceptance (Kim et al., 2018). When OI is high, firms are more willing to accept new ideas, new knowledge and experimentation and, then, transform them into opportunities (Hult et al., 2004; Rhee et al., 2010). Such dexterity facilitates external knowledge-seeking activities. This enables firms to access richer sources of knowledge and accelerate the acquisition of valuable knowledge needed for digital innovation. Furthermore, firms with higher levels of organizational innovativeness are opener to outside knowledge (Kim et al., 2018; Gretsch et al., 2019). Conversely, firms also need to integrate internal and external information and knowledge from external resources, hence being open, in order to enhance their organizational knowledge base and build up their AC (Castro, 2015).

Overall, strong OI has synergies with specialized search, which in turn contributes to the development of AC. It will act as an enabler that makes the openness of firms' specialized search and its engagement with AC stronger. We propose the following hypotheses:

Hypothesis 3. OI enables the positive link from firm's openness in specialized search to AC. The relationship gets stronger when OI is high.

So far we have proposed that absorptive capacity mediates the direct effects of a firm's openness in specialized search on ambidextrous digital process innovation (see Hypotheses H1 and H2). We also proposed that organizational innovativeness positively moderates the relationship between firm's openness in specialized search and absorptive capacity (Hypotheses H3). It is also probable that a high level of organizational innovativeness strengthens the indirect effect of firm's openness in specialized search on the outcomes. Therefore, we predict that the indirect effect of specialized search on ambidextrous digital process innovation via absorptive capacity should be stronger among firms with a high level of organizational innovativeness. Based on the above point, we propose the following Hypothesis:

Hypothesis 4. Organizational innovativeness moderates the strength of the mediated relationship between firm's openness in specialized search and ambidextrous digital process innovation through absorptive capacity.

3. Methodology

3.1. Sampling and data

We survey a sample of coal mining companies in Shanxi Province. This particular focus has two main advantages. First, Shanxi Province is considered to be the first and biggest coal producing province in China and has been so for a long time. It is frequently selected as a typical study

area in the field of energy and resource policy research (e.g., Li et al., 2018; Guo et al., 2016; Fan et al., 2020; Liu et al., 2020). According to the Shanxi Statistical Yearbook, Shanxi produced 16.27 billion tons of coal from 1949 to 2014, accounting for a quarter of the country's total, with a net transfer of more than 11 billion tons, accounting for three quarters of the whole country. Additionally, Shanxi Province, as a "National Resource-Based Economic Transition Comprehensive Reform Pilot Area", has been committed to the transformation of the resource-based economy, with the coal mining industry playing a leading role in the economic transformation as a key enabler (Zhang et al. 2011, 2019). Second, coal mining companies in Shanxi have responded to the government's call for digital transformation by vigorously incorporating digital technologies into the mining process. We did postdoctoral research on a coal company located in Shanxi Province and listed in Fortune 500. For that reason, we chose coal companies as the research object based on the intimate familiarity that we had with this industry. These peculiarities make the data suitable for our analysis.

We use the 2018 Business Directory of coal mining companies of Shanxi Province. The directory is provided by the Shanxi Province's Promotion Association of Resource-based Economic Transformation (SXPARET). We first assign an ID number to each coal company in the directory. We, then, sample firms without replacement using the Basic Package with Sampling Function in R 3.6.1 statistical software. We randomly select 90% of the directory list, that is, 92 coal companies, as our initial sample. The companies in our initial sample were approached with a questionnaire. We distributed and collected the questionnaire in two ways: first, questionnaires were distributed via SXPARET. Second, the authors who are stationed at the Fortune 500 firm mentioned above, distributed the questionnaires to the senior management of the sampled enterprises, using a snowballing approach.

The data were collected during the period from August 2019 to November 2019. We were mindful that digital process innovation is a complex system that involves all the technical aspects of production in a mining firm. Therefore, a total of five questionnaires were distributed to the managers of each firm who supposedly have a comprehensive understanding of technology management. Examples are mine directors, vice mine directors, assistant mine directors and chief engineers. In total, 460 questionnaires were distributed to 92 companies.

A reminder call was made about three weeks after the initial distribution to improve response rate. In the collection process, we eliminated invalid questionnaires, using mutual verification of questionnaires, and selected enterprises that answered all five questionnaires. Our goal was to increase the reliability and quality of the data used for our analysis. The valid questionnaires involve a total of 55 coal mining enterprises and a total of 275 questionnaires. These questionnaires comprise our final analysis sample (275 Respondents) and will be used for the empirical tests. The descriptive statistics for the analysis sample are displayed in Table 1.

Table 1
Descriptive statistics of samples.

Sample characteristics		Number of Firms or Respondents	% of total
Respondents Sex	Male	271	98.55%
	Female	4	1.45%
Respondents Age	Younger than 45 years old	21	7.64%
	From 45 to 55 years old	155	56.36%
	Older than 55 years old	99	36.00%
Respondents Position	Mine directors	55	20.00%
	Vice mine directors	101	36.73%
	Assistant mine directors	78	28.36%
	Chief engineer	41	14.91%
Respondents Education	Junior college and below	111	40.36%
	Bachelor's degree	136	49.45%
	Master's degree and above	28	10.19%
Firm Scale	Produce less than 1.5 million	5	9.09%
	Produce from 1.5 to 2.5 million tons	11	20.00%
	Produce from 2.5 to 3.5 million tons	17	30.91%
	Produce from 3.5 to 4.5 million tons	13	23.64%
	Produce more than 4.5 million tons	9	16.36%
Firm age	Younger than 5 years	2	3.63%
	From 5 to 10 years old	6	10.91%
	From 11 to 15 years old	8	14.55%
	From 16 to 20 years old	15	27.27%
	Older than 20 years	24	43.64%

Note:Respondents=275,Firms=55.

3.2. Measures

We designed the questionnaire based on the issues raised in the existing literature. Through in-depth interviews with 10 managers and academic researchers, we further revised each question to ensure that the wording is clear and valid. Each item is specified as reflective indicators. Tables 2 (see appendix A) and 3 present the scale of latent variables and the correlations among them, respectively. We included firm age and firm scale as control variables in our empirical analysis.

To measure openness of firms' specialized search involving value chain partners and also science-driven search, we essentially adapted the items used in the previous studies (e.g., Aliasghar et al., 2019; Köhler et al., 2012; Sofka and Grimpe, 2010; Laursen and Salter, 2006). These items were based on a 7-point Likert scale, with 1–7 representing 'very low' to 'very high', respectively. We asked participants the extent to which they agree with statements such as "To which extent does your organization search for knowledge on DPI from suppliers" ($\alpha = 0.74$).

To measure absorptive capacity, we used a ten-scale item adapted from Jansen et al. (2005) and Lichtenthaler (2009). These questions were based on a 7-point Likert scale ranging from (1) 'strongly disagree' to (7) 'strongly agree'. We asked participants about the extent to which they agree with statements such as "Our organization is proficient in transforming learned knowledge into strategies and actions" ($\alpha = 0.71$).

Organizational innovativeness was measured using a four-item scale adapted from Ellonen et al. (2008) and Menguc and Auh (2006). These questions use a 7-point Likert scale ranging from (1) 'strongly disagree' to (7) 'strongly agree'. We asked participants the extent to which they agree with statements such as "our organization values rewarding new ideas and solutions." ($\alpha = 0.73$).

To measure exploitative and exploratory DPI, we used items adapted from previous studies on digital innovation and process innovation (Fichman et al., 2014; Nambisan et al., 2017; Monteiro, 2018; Radnejada and Vredenburg, 2019; Un and Asakawa, 2015; Robertson et al., 2012). These questions use a 7-point Likert scale, with 1–7 representing 'very low' to 'very high', respectively. We asked participants the extent to which they agree with statements such as "In the past three years, to which extent has your organization modified, improved existing business processes via digital technologies" ($\alpha = 0.76$).

3.3. Measurement model validation

To test our measurement model, we applied SEM method conducted in the R 3.6.1 software with the "lavaan" package and "semTools" package (Finch and French, 2015). The convergent validity is tested by determining whether the factor loadings for each item are significant, whether their reliability is higher or lower than 0.7 (the minimum criterion value), and whether the Average Variance Extracted (AVE) is higher or lower than 0.5 (the recommended minimum) (Nunnally, 1978; Hair et al., 2010; Fornell and Larcker, 1981).

In Table 2, we apply these tools to our measurement model and report the results. All items are with factor loadings of higher than 0.6, so we do not have to drop any. All the Cronbach's α coefficients and Composite Reliability values are also above the minimum criterion value of 0.70, and the AVE values exceed the recommended minimum of 0.50. Thus, the convergent validity of the measurement model passes the test. Fornell and Larcker (1981) suggest an extra validity test that checks whether the square root of the AVE for each construct exceeds its correlation coefficient with all other constructs. It is an assessment of discriminant construct validity. Table 2 displays these results and shows that the data passes discriminant validity test for each construct.

Our data are cross-sectional and all responses are self-reported. Because of that, there is a possibility that common method bias (CMV) exists. We followed Podsakoff et al. (2012) and applied both ex ante and ex post tactics to reduce the effect of CMV and careless responses. Ex ante, we randomized the order of questionnaire items while ensuring the confidentiality of the responses (Podsakoff et al., 2003, 2012). Ex post, we tested for the common method factor highlighted in Lowry et al. (2013). For this test all observable variables were loaded onto a common latent factor. The results showed that CMV accounted for 36.7% of the total variance, which is below the 50% threshold recommended by Lowry et al. (2013). Subsequently, CMV is not having a strong influence on the results of this study.

4. Results

In this section, we test the hypotheses stated in Section 3 regarding the link between specialized search and ambidextrous DPI and its mediating and moderating mechanisms.

4.1. Assessment of the structural model and mediating effects test

We begin by a path analysis to examine the relationships. These results are shown in Table 4. We find that the relation is not always statistically significant. Specifically, the relationship from "*VCPS*" and "*SCIS*" to "*EIDPI*" are positive and significant (β = 0.223; se = 0.091 and β = 0.149; se = 0.104, respectively). However, "*VCPS*" and "*SCIS*" have a positive but not significant effect on *ERDPI* (β = 0.082 and β = 0.050, respectively). Moreover, the results show that *VCPS* demonstrates a stronger positive effect than *SCIS* on *EIDPI* (β = 0.223 and β = 0.149, respectively). These observations lend support to Hypothesis H1a, but Hypothesis H1b is not supported. The results are summarized in Table 4.

To test for the mediating effect of *AC*, we do a decomposition of effects. To do so, we disaggregate the total effect of an independent variable on a dependent variable into its indirect and direct effects. According to Rhee et al. (2010), the presence of an indirect effect indicates that a significant part of the link between the dependent and independent variable is explained via the mediate variable. These results are shown in Table 4. We observe that ① there is a significant effect from *VCPS* (β = 0.350, t = 4.95) and *SCIS* (β = 0.243, t = 3.50) on *AC*, and ② there is a significant effect from *VCPS* and *SCIS* on *EIDPI*. ③ There is also a very significant effect from *AC* (β = 0.323, t = 4.25; β = 0.294, t = 3.67) on both *EIDPI* and *ERDPI*.

Table 4 is also showing the indirect effects. The results indicate that ① there is a significant indirect effect of *VCPS* (β = 0.113, t = 3.39) on *EIDPI* through *AC* as the mediator; ② there is a significant indirect effect of *VCPS* (β = 0.103, t = 3.04) on *ERDPI* through *AC* as the mediator. ③ There is a significant indirect effect of *SCIS* (β = 0.078, t = 2.80 and β = 0.071, t = 2.59) on both *EIDPI* and *ERDPI* through *AC* as the mediator. Altogether, these results indicate that ① *AC* partially mediates between firm's openness in specialized search and *EIDPI*, and ② *AC* fully mediates between firm's openness in specialized search and *ERDPI*. We, then, followed Preacher and Hayes (2008) and performed a non-parametric bootstrapping procedure to assess the indirect effect of firm's openness on DPI as it happens through *AC*. The "lavaan" package in R was used to examine this aspect and obtain bootstrapped confidence intervals (CIs) for each indirect effect. We conduct 10,000 bootstrap replicates to generate the estimates. These estimates are shown in Table 4. We find that our results are robust because the bias-corrected CIs do not include zero. We also conduct Sobel-Goodman test to analyze the mediating effect.

As shown in Table 5, four equations of indirect effect are used to estimate the mediation role, and the results show that the effect is significant with a z value of larger than 2.

4.2. Moderated mediation analysis

Hypothesis 3 proposes *OI* positively moderates the influence of firm's openness in specialized search on AC. In Table 6 we look at the evidence. The results prove that *OI* indeed has a positive effect on the whole relationship. That is to say, the higher levels of *OI* there are, the stronger the influence of firm's openness in specialized search on AC, in support of H3.

Hypothesis 4 assumes that, when organizational innovativeness is high, absorptive capacity has a stronger mediating effect on firm's openness in specialized search and ambidextrous DPI. To test this hypothesis, we follow Paškvan et al. (2016) and conducted a bootstrapping test using R 3.6.1 software to estimate an Index of Moderated Mediation (IMM). The sample size and confidence interval are set to 10,000 and 95%, respectively. The results appear in panel A of Table 5. The indirect effect of two structural equation model is significant (95% CI [0.070, 0.245] and 95% CI [0.035, 0.198], respectively). The IMM is significant for EIDPI, 95% CI [0.038, 0.406] and for ERDPI, 95% CI [0.013, 0.303] (see Table 6). The above results imply that organizational innovativeness positively moderates the indirect positive effects of firm's openness in specialized search on ambidextrous DPI via AC. As hypothesized, the strength of the mediated relationship between firm's openness in specialized search and ambidextrous DPI through AC is stronger for firms with a high level of organizational innovativeness.

Table 2
Mean, standard deviation, correlations and discriminant validity test.

Variable	Mean	SD	1	2	3	4	5	6
1.VCPS	4.22	0.98	1					
2.SCIS	3.9	0.97	0.049	1				
3.AC	3.99	1	0.347	0.249	1			
4.OI	4.34	1.03	0.089	0.091	0.083	1		
5.EIDPI	4.21	1.08	0.326	0.217	0.434	0.222	1	
6.ERDPI	4.18	1.13	0.186	0.13	0.325	0.181	0.422	1

We also conduct a goodness-of-fit test: chi-squared divided by degrees of freedom = 335/332.35, GFI = 0.923, AGFI = 0.906, CFI = 0.997, TLI = 0.997, PGFI = 0.761, PNFI=0.800, RMR = 0.064, and RMSEA =0.001. As shown in Table 3, nine goodness-of-fit indices comply with the required standards (Mulaik et al., 1989; Byrne, 1998), thus, our model has a reasonably good fit with the collected data. Overall, we find our measurement model has adequate convergent validity and discriminant validity and its goodness-of-fit is at a satisfactory level.

5. Conclusions, contributions and implications

5.1. Conclusions

Recent transformative endeavors have led to an increasing application of digital technologies and a rising awareness among Chinese coal companies' managers that DPI is critical to the future of the coal industry. While the digital transformation of the mining sector is moving forward, the barriers to acquiring external knowledge that would facilitate DPI still remain. This study has attempted to offer more insight into the issues that support development of DPI. Drawing on open innovation and digital innovation literature, this paper examines which search strategies for external knowledge are more effective in digital process innovation and for process-oriented firms. We use a moderated

Table 3
Goodness-of-fit of the measurement and structural model.

Model	chisq/df	GFI	AGFI	CFI	TLI	PGFI	PNFI	RMR	RMSEA
Measurement model	1.008	0.923	0.906	0.997	0.997	0.761	0.8	0.064	0.001
Structural model	1.015	0.919	0.903	0.996	0.997	0.765	0.793	0.074	0.008
Goodness-of-fit criteria	<3	>0.9	>0.9	>0.9	>0.9	>0.5	>0.5	<0.08	<0.08

Table 4
Results of path coefficients analysis and hypotheses testing.

Type	latent variable	VCPS		SCIS		AC	
		Std. path coeff.	Bias-corrected 95% CI	Std. path coeff.	Bias-corrected 95% CI	Std. path coeff.	Bias-corrected 95% CI
Direct effects	*AC*	0.350*** (4.95)	[.262, .605]	0.243*** (3.5)	[.157, .557]	/	
	EIDPI	0.223** (2.94)	[.089, .448]	0.149* (2.05)	[.009, .416]	0.323*** (4.25)	[.169, .458]
	ERDPI	0.082 (1.04)	[-.082, .269]	0.05 (0.51)	[-.132, .270]	0.294*** (3.67)	[.126, .415]
Indirect effects	*AC*	/		/		/	
	EIDPI	0.113** (3.39)	[.057, .215]	0.078** (2.8)	[.034, .190]	/	
	ERDPI	0.103** (3.04)	[.042, .193]	0.071** (2.59)	[.023, .170]	/	
Total effects	*AC*	0.350*** (4.95)	[.262, .605]	0.243*** (3.5)	[.157, .557]	/	
	EIDPI	0.336*** (4.44)	[.226, .583]	0.227** (3.06)	[.116, .532]	0.323*** (4.25)	[.169, .458]
	ERDPI	0.185* (2.45)	[.042, .379]	0.122 (1.72)	[-.025, .365]	0.294*** (3.67)	[.126, .415]

Note: * p-value <0.05; ** p-value <0.01; *** p-value <0.001.

Table 5
Sobel, Aroian, and Goodman test for mediation effects analysis.

Constructs of measurement	Relationship of constructs	Unstandardized regression weight	se	Sobel test	Aroian test	Goodman test
VCPS—AC—EIDPI	*VCPS—AC*	0.433	0.088	3.21**	3.17**	3.25**
	AC—EIDPI	0.313	0.074			
VCPS—AC—ERDPI	*VCPS—AC*	0.433	0.088	2.93**	2.89**	2.97**
	AC—ERDPI	0.270	0.074			
SCIS—AC—EIDPI	*SCIS—AC*	0.357	0.102	2.70**	2.65**	2.74**
	AC—EIDPI	0.313	0.074			
SCIS—AC—ERDPI	*SCIS—AC*	0.357	0.102	2.53*	2.48*	2.58**
	AC—ERDPI	0.270	0.074			

Note: * p-value <0.05; ** p-value <0.01; *** p-value <0.001.

mediation model to explore.

The empirical results show that both types of specialized search strategies have a positive influence on development of exploitative DPI. Value chain partner-driven search entails a stronger positive effect on exploitative DPI than science-driven search, but shows no direct effect on exploratory DPI. In this process, absorptive capacity mediates the effect of firm's openness in specialized search on ambidextrous DPI. Furthermore, when the firm has a high level of organizational innovativeness, specialized search will have stronger positive effect on ambidextrous DPI via absorptive capacity.

5.2. Theoretical implications

This study offers a new framework for developing digital process innovation in process-oriented firms. This framework is developed by extending previous research on searching externally for emerging knowledge, the role of absorptive capacity and organizational innovativeness in driving innovation, and digital innovation. The framework outlines how mining firms become digital process innovators; an area still needing much discussion.

First, the paper contributes to the open innovation and digital innovation literature by providing empirical evidence from Chinese mining sector that the firm's openness in specialized search strategies is related to the two types of digital process innovations. To our knowledge, this topic has received only very limited attention in the literature. We propose that value chain partner-driven search and science-driven search are two strategies for a firm to conduct a specialized search. These two strategies are more applicable to firms in the process industries than the traditional search strategies such as search depth and breadth strategies, which have been widely studied for manufacturing firms (e.g., Ferreras-Mendez et al., 2015; Flor et al., 2018). We study innovation in the form of an ambidextrous form, exploitative and exploratory DPI, to get more detailed insight into the use of digital technology. Such level of details is not covered in previous similar researches on digital innovation. Our findings reveal that value chain partner-driven search has a stronger effect on the development of exploitative DPI than science-driven search, supporting Hypothesis H1a. The results extend the empirical research on the relationship between specialized search and conventional innovation by providing new evidence of the positive link across different types of process innovation. In relation to H1b, we find that both search strategies have no direct impact on the development of exploratory DPI, leading to the rejection of Hypothesis H1b. This lack of connection reveals that developing exploratory DPI that relies only on conducting external search strategies may not be enough. One possible explanation is that developing exploratory DPI requires not only openness to external knowledge, but also the

Table 6
Results of moderated mediation analysis.

Panel A: Moderated mediation model						
DV (mediator variable model)		AC				
		Bootstrapped95% CI			Bootstrapped95% CI	
	Std. coeff.	*LL*	*UL*	*Std. coeff.*	*LL*	*UL*
VCPS	.379 (5.20)	0.294	0.651	.391 (5.33)	0.308	0.666
OI	.047 (0.71)	−0.102	0.218	.051 (0.77)	−0.097	0.223
*VCPS*OI*	.252 (2.75)	0.191	0.741	.248 (2.71)	0.182	0.736
DV (dependent variable model)	*EIDPI*			*ERDPI*		
		Bootstrapped95% CI			*Bootstrapped95% CI*	
	Std. coeff.	*LL*	*UL*	*Std. coeff.*	*LL*	*UL*
AC	.343 (4.40)	0.185	0.482	.256 (3.16)	0.091	0.389
VCPS	.217 (2.80)	0.079	0.447	.114 (1.61)	−0.052	0.319
Controls	Yes			Yes		
Index of Moderated mediation	.086 (2.36)	0.038	0.406	.063 (2.13)	0.013	0.303
Additional parameter (IND)	.131 (3.53)	0.070	0.245	.101 (2.80)	0.035	0.198
Panel B: Moderated mediation model						
DV (mediator variable model)		*AC*				
		Bootstrapped95% CI			*Bootstrapped95% CI*	
	Std. coeff.	*LL*	*UL*	*Std. coeff.*	*LL*	*UL*
SCIS	0.261 (3.55)	0.173	0.600	0.275 (3.73)	0.193	0.619
OI	0.108 (1.49)	−0.043	0.311	0.125 (1.72)	−0.022	0.332
*SCIS*OI*	0.156 (1.70)	−0.048	0.669	0.204 (2.18)	0.040	0.772
DV (dependent variable model)	*EIDPI*			*ERDPI*		
		Bootstrapped95% CI			Bootstrapped95% CI	
	Std. coeff.	*LL*	*UL*	*Std. coeff.*	*LL*	*UL*
AC	0.360 (4.94)	0.214	0.497	0.303 (3.95)	0.143	0.425
SCIS	0.146 (1.98)	0.002	0.426	0.051 (0.67)	−0.137	0.278
Controls	Yes			Yes		
Index of Moderated mediation	0.056 (1.68)	−0.018	0.239	0.062 (1.93)	−0.002	0.232
Additional parameter (IND)	0.094 (3.01)	0.048	0.227	0.084 (2.78)	0.034	0.196

Note: * p-value <0.05; ** p-value <0.01; *** p-value <0.001; t-value in parentheses; CI = Bias-corrected 95% confidence interval; LL = lower limit; UL=upper limit; Additional parameter (IND) = indirect effect.

capacity to assimilate and exploit knowledge. We call the latter absorptive capacity. Taken together, the findings address concerns by Lopez-Vega et al. (2016) and Terjesen and Patel (2017), where they suggest that more research on the relationship between firm's openness in external search and different types of innovation is warranted.

Second, the paper contributes to the absorptive capacity literature by providing empirical insights from process-oriented mining enterprises. The findings support the view that AC may play a mediating role in openness–innovation relationship (e.g.,Ferreras-Mendez et al., 2015; Aliasghar et al., 2019). Based on these results, we could accept Hypothesis H2. Scrutinizing the mediating role of AC, our findings reveal that the mediating effect of AC might extend beyond the picture currently provided by the existing research. Specifically, AC partially mediates the link from openness of firm's specialized search to development of exploitative DPI. This result is consistent with the impact of mediating role of absorptive capacity on conventional (incremental) process innovation proposed by Aliasghar et al. (2019). More importantly, we find that AC has a fully mediating effect on openness of firms' specialized search and exploratory DPI. The findings highlight that no matter how open the firm is to external knowledge, the openness of firm's specialized search is not a direct indicator of exploratory DPI. To channel external specialized knowledge and expertise into exploratory DPI, mining firms must first internalize this external knowledge by assimilating and combining it with the internal stock of knowledge. However, the two different mediating roles absorptive capacity plays in this process have been unexplored in the previous works of this kind. We partially fill this gap by identifying and specifying those roles.

Third, our study extends research on organizational innovativeness and furthers the understanding of AC and ambidextrous DPI. We find that the organizational innovativeness not only moderates the links between firm's openness in specialized search and AC, but also positively moderates the indirect effects of firm's openness in specialized search on ambidextrous DPI via AC, in support of Hypotheses H3 and H4. Although existing research have identified the relationship between external knowledge search and AC, there has been no discussion of contingent factors in facilitating AC (Gretsch et al., 2019). This paper partially fills this gap by inserting organizational innovativeness into the discussion as moderating factor in the link between specialized search and AC. Furthermore, previous research on the relationship between external knowledge search and innovation activities is limited to mediation models such as Gao et al. (2019). This paper provides further understanding of the moderated mediation effect model by highlighting that AC has a stronger mediating role when there is a high level of organizational innovativeness. As such, we emphasize the importance of organizational innovativeness in coal mining enterprises.

5.3. Managerial implications

Besides its theoretical contributions, this study presents several guidelines for mining managers who intend to raise the level of digitalization in their process innovation by addressing the managerial tools and tactics needed for achieving such goal.

Firstly, it is necessary for mining managers to configure the suitable search strategy when approaching digital process innovation. our findings emphasize that for successful development of exploitative DPI, managers in Chinese coal mining sector tend to prioritize knowledge acquisition and utilization from value chain partners rather than from universities or research organizations, since the knowledge acquired from value chain partners is closer to the company's own knowledge. This approach does not mean that firms' science-driven search strategies are ineffective. Rather, it highlights the difficulties associated with finding and assimilating novel theoretical knowledge from universities or research organizations. In addition, mining managers can also use the findings from this study as a guideline to plan for the development of exploratory DPI. Mining sector managers may not initially be able to develop DPI at a fast pace. The reason is that it is unrealistic to rely exclusively on specialized searches due to the complexity of exploratory process innovation. Managers should be aware that steadily developing absorptive capacity is critical to the development of exploratory DPI.

Secondly, it is advisable for mining managers to build an adequate level of capacity for the absorbing of external knowledge so that they

can benefit from external partners and their knowledge in the interest of conducting their own digital process innovation. Our results show that absorptive capacity does serve as a mediator between the mining firm's specialized search strategies and digital process innovation. Exploratory DPI is particularly dependent on absorptive capacity, since external knowledge needs to be transferred and internalized in the learning process. Thus, implementing initiatives to promote absorptive capacity can be a prudent measure if a mining firm intends to maximize its benefit. More precisely, mining managers should develop initiatives to raise their AC for knowledge transformation and knowledge exploitation. In turn, they are better poised to collaborate with external partners and become more innovative in exploratory digital process.

Thirdly, mining firms should consider raising their level of organizational innovativeness. Coal mining industry has long been regarded as having a conservative culture resistant to change. This attitude has put barriers in the way of innovative activity. Our framework highlights that mining managers should be aware of these issues and intensify firms' innovativeness by cultivating an innovative atmosphere. They should also have the willingness to change, seek out new ways to do things, and try out innovative ideas. Combining these practices with external partners (e.g., equipment suppliers, universities) will allow mining enterprises to gain more innovative experiences in the process of exchanging ideas. Thereby, mining managers will have the prowess to facilitate the flow of information from collaborating external partners and other sources in the firm, in turn, raise the absorptive capacity of the firm.

5.4. Limitations and future research

There are a few limitations and avenues for future research. First, since the study is cross-sectional in design, it is limited in its ability to infer causal relationships between the factors in the research. A longitudinal study can provide more support to the findings of this paper. Second, the sample is restricted to coal mining firms in a certain province of China. The results might not be easily generalized to other process-oriented industries such as oil-production industry for this reason. In future, it would be interesting to study other industries and see whether the results hold the same. Third, it would be interesting to study the role of other mediating and contingency factors beyond AC and OI.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table 2
Latent variables measurement scales: Reliability and convergent validity tests.

Items	Latent constructs	SFL
	Value chain partner-driven search (α=0.803; CR=0.805; AVE=0.510)	
VCPS1	To which extent does your organization search for knowledge on digital process innovation from ICT suppliers.	0.738
VCPS2	To which extent does your organization search for knowledge on digital process innovation from competitors.	0.721
VCPS3	To which extent does your organization collect opinions and suggestions on digital process innovation from industry associations.	0.703
VCPS4	To which extent does your organization search for knowledge on digital process innovation from consulting firms.	0.702
	Science-driven search (α=0.780; CR=0.787; AVE=0.502)	
SCIS1	To which extent does your organization search for knowledge on digital process innovation from universities.	0.679
SCIS2	To which extent does your organization search for knowledge on digital process innovation from research organizations.	0.703
SCI3	To which extent does your organization search for knowledge on digital process innovation from government research agencies.	0.765
SCI4	To which extent does your organization search for knowledge on digital process innovation through professional conferences or forums.	0.611
	Absorptive capacity (α=0.919; CR=0.920; AVE=0.537)	
AC1	Our organization frequently searches for external sources of new knowledge and skills.	0.764
AC2	Our organization analyzes the usefulness of new external knowledge for our existing knowledge.	0.745
AC3	Our organization records and stores newly acquired knowledge for future reference.	0.773
AC4	Our organization has the ability to integrate newly acquired knowledge into current ways of doing things.	0.699
AC5	Our organization constantly considers how to exploit newly acquired knowledge, skills, and digital technologies.	0.763
AC6	Our organization is proficient in transforming learned knowledge into strategies and actions.	0.712
AC7	Our organization employs communication channels for employees to share information and practical experience.	0.683
AC8	Our employees often exchange ideas on learned knowledge to improve performance.	0.732
AC9	Operations, marketing, and supply chain functions regularly share information and interpret its implications.	0.716
AC10	The activities of our functional units are tightly coordinated to ensure better use of our acquired knowledge.	0.734
	Organizational innovativeness (α=0.818; CR=0.820; AVE=0.535)	
OI1	Our organization strives to find new ways to manage business.	0.710
OI2	Our organization encourages employees to think positively and adopt new ways of doing things.	0.734
OI3	Our organization values rewarding new ideas and solutions.	0.727
OI4	Our organization is dedicated to building a learning and transformative corporate culture.	0.749
	Incremental digital process innovation (α=0.804; CR=0.806; AVE=0.581)	
EIDPI1	In the past three years, to which extent has your organization modified, improved existing business processes via digital technologies.	0.761
EIDPI2	In the past three years, to which extent has your organization strengthen current digital technologies.	0.789
EIDPI3	In the past three years, to which extent has your organization adopt process technology from other companies.	0.733
	Radical digital process innovation (α=0.798; CR=0.798; AVE=0.567)	
ERDPI1	In the past three years, to which extent has your organization invested in purchasing new digital technology for process.	0.799
ERDPI2	In the past three years, to which extent has your organization created new business processes via digital technologies.	0.714
ERDPI3	In the past three years, to which extent has your organization invested in R&D on digitization dedicated to process innovation.	0.746

Note: SFL = standardized factor loading; α = Cronbach's alpha; CR = composite reliability; AVE = average variance extracted.

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