Process Innovation in Small and Medium-sized Enterprises: The Critical Roles of External Knowledge Sourcing and Absorptive Capacity

Abstract: Although previous studies have contributed substantially to our understanding of the role of external collaboration on product innovation in the context of high-tech industries in developed countries, there has been limited attention to the role of knowledge search on process innovation in small and medium-sized enterprises (SMEs) operating in extreme institutional environments. Drawing on the open innovation and absorptive capacity literatures, two key findings emerge from our study of 124 SMEs operating in the automotive industry. First, we find that external knowledge search breadth, but not depth, is related to the development of process innovation. Second, process innovation is positively related to performance.

Keywords: open innovation, process innovation, absorptive capacity, attention-based theories, search depth, search breadth,

1. Introduction

It is widely acknowledged that tapping into external sources can enhance an organization's knowledge stock, create opportunities for managers to develop innovation (Rosenkopf and Nerkar 2001), and influence the firm's ability to enhance its innovation performance (Spender and Grant 1996). The notion of drawing in knowledge from the outside has been the subject of various studies that have aimed to examine how firms develop the knowledge necessary for fostering competitive positions in international markets (Laursen and Salter 2006; Lee, Park, Yoon, and Park 2010; Love, Roper, and Vahter 2014; Van de Vrande, De Jong, Vanhaverbeke, and De Rochemont 2009). However, most of the existing empirical evidence is based on studies of large, high-tech firms from developed countries (exceptions are Lee, Park, Yoon, and Park 2010; Muscio 2007; Parida, Westerberg, and Frishammar 2012).

We still know relatively little about the circumstances under which small- and medium-sized enterprises (SMEs) operating in lower-tech industries can benefit from open innovation. SMEs, with more limited internal resources, are likely to rely on external collaborations to expand their innovation activities (Edwards, Delbridge, and Munday 2005). Chesbrough and Crowther (2006) note that firms operating in lower-tech industries stand to benefit from open innovation, but that they may apply different external knowledge search strategies in their innovation activities, relative to the large, knowledge-intensive firms that have received more attention in this regard (Spithoven, Clarysse, and Knockaert 2011).

This study aims to contribute to our understanding by studying SMEs that operate in a mature industry, in the context of a challenging institutional environment. We examine whether, and under what conditions, firm openness can lead to the development of process innovation and, subsequently, translate into performance outcomes. In exploring this question, our study makes three contributions to the existing literature. First, we explore, theoretically and empirically, the ways in which knowledge search – considering both *depth* and *breadth* –

can help firms to enhance their process innovation. In so doing, we respond to a recent call from Davis and Bendickson (2020) for more research on the inter-organizational antecedents of innovation in SMEs. In addition, we extend the literature by focusing on process innovation, which has been a rather under-researched topic. Traditionally, innovation scholars have focused primarily on SMEs' new product development (Nieto, Santamaria, and Fernandez 2015; Madrid-Guijarro, García-Pérez-de-Lema, and Van Auken 2013; Rammer, Czarnitzki, and Spielkamp 2009; De Jong, and Vermeulen 2006; De Massis, Frattini, Pizzurno, and Cassia 2015), as opposed to the development of process innovation (Hervas-Oliver, Boronat-Moll, and Sempere-Ripoll 2016; Abernathy, and Utterback 1978; Linton, and Walsh 2003; Pisano 1997; Utterback 1994). Linton and Walsh (2008) note that, compared to product innovation, process-related innovation activities require different knowledge search strategies and managerial decisions. As Un and Asakawa (2015, p. 140) argue, "differences between product and process innovation in their innovation mechanisms explain why insights from analysing product innovation may not be applied directly to the analysis of process innovation".

Second, we shed light on the mechanisms that underpin openness and the development of process innovation, by examining the role of absorptive capacity (AC) in the relationship between external search and process innovation. Some scholars position AC alongside the firm's external knowledge search and innovation-related activities (Laursen and Salter 2006), treating it as a complementary factor and often viewing it as a unidimensional concept operationalized using R&D intensity. However, other studies have cast serious doubt on the appropriateness of this single-item measurement approach and called for treating AC as a complex and multifaceted phenomenon and, accordingly, adopting a multidimensional approach to its measurement (Aliasghar, Rose, and Chetty 2019a; Volberda, Foss, and Lyles 2010; Zahra and George 2002).

Finally, the research that has been carried out on the relationship between knowledge search and innovation outcomes has been based mainly on data drawn from developed-nation firms operating in high-tech industries (Linton and Walsh 2008). This raises questions about the applicability of these findings for firms operating in lower-tech sectors in emerging economies, as the nature of this relationship is likely to be subject to country- and industry-specific characteristics, especially for SMEs. This paper attempts to address this research gap by focusing on SMEs in the Iranian automotive industry and exploring whether firms operating in an emerging economy, and under international sanctions, can benefit from openness to improve their performance. International sanctions mean that Iranian firms, including the SMEs that form part of the country's automotive value chain, have been operating under substantial limitations for several decades. The sanctions have created severe limitations on firms' access to novel technologies. As a result, the technology being used in this sector is rather old; this has led to the manufacture of vehicles that cannot meet international standards, with respect to safety and design (Wilman and Bax 2015).

While we study open innovation and AC in Iran, the findings of this research can also apply to firms in other nations that are subject to limitations on their international trade activities (Aliasghar, Rose, and Chetty 2019b). This also responds to a recent call for research on extreme contexts, by Hällgren, Rouleau, and De Rond (2018), who argue that it is important to understand more about how firms respond to sudden and extreme changes in their environments. Extreme contexts can be sources of valuable learning for other contexts, when unexpected and out-of-the-ordinary shocks occur. For instance, the COVID-19 pandemic that is currently ravaging the world has resulted in disruptions in supply chains and increased production costs. The duration of these effects remains unclear at this point, but some industries (e.g., tourism) seem likely to face severe difficulties with respect to recovery in the longer term. These disruptions impose restraints on firms that are have similarities to those faced by Iranian

firms, such as restricted access to international supply chains, changes in the nature of interactions with international partners, and limitations on the learning and systematic knowledge transfer that can be achieved through visiting partners' manufacturing facilities and observing their operations (e.g., Aliasghar, Rose, and Chetty 2019b; Shenkar and Li 1999).

As such, our findings in the extreme context of Iran have broader implications, particularly during times of crisis. Our work contributes to understanding regarding how the breadth and depth of external knowledge search are related to the development of process innovation and subsequent performance, and how absorptive capacity mediates the search-innovation relationship, even among SMEs operating in a constraint-heavy environment.

2. *Literature Review and Theoretical Development*

2.1. Open innovation

Traditionally, innovation outcomes have been viewed as being influenced primarily by in-house R&D activities. For decades, internal R&D has been seen as a valuable strategic asset for gaining and sustaining competitive advantage. Managers spend precious resources generating R&D capabilities, hoping that they might, in turn, exploit the outcomes of the investments (Teece 1986). In the *closed* innovation model, "a company generates, develops and commercializes its own ideas" (Chesbrough 2006, p.36). Advocates of this closed innovation approach hold that firms can outperform their rivals and experience successful advances by expanding their R&D activities through increasing budgets and controlling the entire process of innovation, from idea generation to production of the final product (Chesbrough 2006).

In contrast, Chesbrough (2006, p. 1), who first coined the term, defines *open innovation*, as "…purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively". Past research provides successful examples of firms, such as IBM, BellSouth, and P&G, that have moved away from

depending solely on investing in their internal research to deliberately searching for technological solutions from outside of their boundaries (Chesbrough and Crowther 2006). Open innovation allows managers to access more sources and to expand their innovation through external channels. However, the process of recognizing the technological solutions that can be integrated with the firms' internal knowledge stocks requires managers to intentionally search for, and identify, appropriate external sources. The notion of external knowledge search has been noted as a crucial mechanism for developing innovation activities and for helping firms to evolve (Köhler, Sofka, and Grimpe 2012). Huston and Sakkab (2006, p. 3) assert that managers need to shift their firms' attitudes from "resistance to innovation not invented here to enthusiasm for those proudly found elsewhere".

Two key components of external knowledge search have been identified as *depth* and *breadth* (Laursen and Salter 2006). External search breadth refers to the number and diversity of external sources that a firm depends on to develop its knowledge stock. The second component, search depth, refers to "the extent to which firms draw deeply from different external sources or search channels" (Laursen and Salter 2006, p. 134). Most previous studies have investigated the role of external linkages on product innovation in large, high-tech companies (Van de Vrande, De Jong, Vanhaverbeke, and De Rochemont 2009). The antecedents to process innovation remain under-researched (e.g., Lee, Park, Yoon, and Park 2010).

While SMEs are critical sources for innovation and economic development, their knowledge search strategies and innovation activities differ from those of large firms. Typically, SMEs are more flexible, and faster at making strategic decisions, but have fewer financial and non-financial resources available for in-house research (Brunswicker, and Vanhaverbeke 2015). Van de Vrande, De Jong, Vanhaverbeke, and De Rochemont (2009, p. 426) note that "SMEs need to heavily draw on their networks to find missing innovation

resources, and due to their smallness, they will be confronted with the boundaries of their organizations rather sooner than later". It is, thus, critical for SME managers to know where to search for technological ideas, especially in their efforts to develop process innovation.

Utterback and Abernathy (1975, p. 641) define process innovation as "the system of process equipment, workforce, task specifications, material inputs, work and information flows, etc. that are employed to produce a product or service". They note that product-related innovation is especially crucial in the early stages of a product's life cycle. However, after buyers and sellers gain more experience with both the product and the market, the emergence of a dominant design is likely to shift the focus more toward process-related innovation as a source of competitive advantage (Linton and Walsh 2003; Linton and Walsh 2008; Anderson and Tushman 1990; Oltra and Saint Jean 2009; Barras 1986). In the context of services, however, Barras (1986) proposes a "reverse product cycle", such that process innovation occurs first, to enhance the efficiency of the delivery of current services, with novel offerings then introduced at a later time.

Process innovation plays a pivotal role in the quest to gain competitive advantage, especially in a turbulent business environment (Linton and Walsh 2008; Barnett and Clark 1996). It offers the potential for profound influence on a firm's performance, through reduced expenses (Bernstein and Kök 2009), enhanced efficiency, and both operational and product quality (Reichstein and Salter 2006). Process innovation is particularly important for SMEs; their lower levels of resources and slack mean that efficiencies arising from effective process innovation can be especially valuable. Industry characteristics are also salient; Saranga, Schotter, and Mudambi (2019) note the importance of cost competitiveness in the mature automotive industry, which makes it extremely important for firms to search for new ways to obtain the capabilities necessary for developing their manufacturing operations in order to sustain their market positions (Aliasghar, Rose, and Chetty 2019b).

2.2. Knowledge Search Strategies

Laursen and Salter (2006) note that external knowledge depth and breadth can provide firms with novel solutions and capabilities that assist in the development of product innovation. Amara and Landry (2005) indicate that searching deeply and widely facilitates product innovation. However, research on external linkages have tended to focus on the development of product innovation (e.g., Katila and Ahuja 2002); process innovation has received much less attention in the literature (exceptions include Hervas-Oliver, Boronat-Moll, and Sempere-Ripoll 2016; Terjesen and Patel 2015), and some important questions remain unanswered. For example, we have limited understanding about the antecedents of process-related innovation activities (Keupp, Palmié, and Gassmann 2012).

Searching broadly enables a firm to access a wide range of information, pertaining to aspects as diverse as new markets and technological advances (Ferreras-Méndez, Newell, Fernández-Mesa, and Alegre 2015). Previous research has addressed the nature of the relationship between broad search and product innovation, finding evidence of both positively linear and inverted-U relationships (Katila and Ahuja 2002). There is, however, reason to believe that the relationship between broad search and process innovation may be different, especially for SMEs operating in a mature industry. First, searching broadly may present firms with too many new ideas from which to select. Koput (1997) notes that, while searching for a large set of potential solutions offers the firm many technological ideas, they may not be applicable at that time, creating cognitive and managerial overload. Employing many search channels, absent the internal routines and capabilities that are necessary in order for the firm to support a large number of relationships, may create confusion for SME managers, who require both understanding of the potential of newly-generated ideas and the ability to exploit the new knowledge within the firm (Terjesen and Patel 2015).

Search breadth can offer the firm access to know-what and codified knowledge, but it may not facilitate ready access to tacit knowledge (Lowik, van Rossum, Kraaijenbrink, and Groen 2012; Zaheer, Gözübüyük, and Milanov 2010). This is an important distinction, as the nature of process-related innovation activities is likely to be tacit and complicated, relative to product innovation (Un and Asakawa 2015), which means that absorption and assimilation occur more readily through direct interactions between partners, rather than through arms-length contractual channels (Barney 1991). SMEs, particularly those operating in relatively extreme contexts, may suffer from limitations with respect to both R&D budgets and innovation capacity. These firms are unlikely to have independent R&D functions, or the organizational slack or specialized resources needed to be deeply involved in the development of process innovation, which is, by nature, more complex than product innovation to acquire and assimilate(Spithoven, Clarysse, and Knockaert 2011; Terjesen and Patel 2015).

The institutional context also plays a role, and limitations regarding international interactions create difficult-to-surmount barriers for SMEs interested in searching across national borders for new knowledge and technologies. As a relatively extreme example, sanctions have prevented many foreign firms, particularly those in Europe, from supplying goods or transferring knowledge to their Iranian counterparts. These limitations mean that Iranian firms lack direct access to a diverse range of global sources of knowledge, especially from advanced countries, that would allow them to acquire and assimilate novel technologies aimed at developing their operations.

Second, integrating ideas generated from external partners into the firm, to create process innovation, requires specific capabilities, comparable to those associated with research and development (Terjesen and Patel 2015). SME managers may find it necessary to adjust internal operational routines in order to exploit newly-acquired knowledge aimed at developing process innovation, which may be quite costly in terms of finances and human resources. These

costs are likely to especially high – potentially outweighing the benefits – for firms that are trying to generate complicated and systematic process innovations (Ettlie and Reza 1992). Consistent with attention-based theory, SMEs need to "concentrate their energy, effort, and mindfulness on a limited number of issues" to develop innovation-related activities (Ocasio 1997, p. 203). Managerial consideration is widely considered to be a particularly valuable resource within the organization, and decisions regarding the allocation of other resources, both financial and non-financial, to specific activities provides insight into why some SMEs are better than others, in terms of both taking advantage of external linkages and introducing new processes.

In sum, while search breadth may provide access to a wider range of external sources, it does not guarantee the efficient realization of newly-acquired knowledge for the development of process innovation in the receiving firm (Terjesen and Patel 2015). Simultaneous collaboration with multiple external partners may result in higher marginal costs, especially for small firms (Duysters and Lokshin 2011). Managing broad and heterogenous sources of knowledge requires a more substantial share of managerial time and attention; in slack-hungry SMEs, this attention is likely to be pulled from other critical issues (Lowik, van Rossum, Kraaijenbrink, and Groen 2012). The costs may be particularly high in the case of trying to generate complicated process innovation. Focusing on search breadth to obtain sustainable sources of novel technologies for process innovation may lead to unsatisfying results for SMEs, especially those operating in difficult institutional environments. Therefore, we propose the following hypothesis:

> ***Hypothesis 1:*** *External search breadth is negatively related to the development of process innovation in SMEs.*

The second knowledge strategy that firms can apply to search for novel solutions is to build deep relations with a limited number of external actors (Laursen, and Salter 2006).

Considerable attention has been given in the literature to the potential costs and benefits of knowledge search depth from external sources in terms of product innovation (e.g., Laursen, and Salter 2006; Ferreras-Méndez, Newell, Fernández-Mesa, and Alegre 2015). However, there is extremely limited evidence related to the impact of external search depth on the development of process innovation, particularly in SMEs.

Process innovation is typically cumulative and embedded in organizational mechanisms and routines (Nelson and Winter 1982). Its embeddedness means that process innovation is often the outcome of intense and direct relationships between partners (Zaheer, Gözübüyük, and Milanov 2010; Phelps 2010; Teece 1992). Through deep relationships, firms expand common routines, norms, and language, which enable the development of process-related innovation (Laursen and Salter 2006). The absorptive capacity literature argues that such collaborations, which are characterized by deeply social interaction mechanisms, are likely to lead to more acquisition, transformation, and exploitation of tacit knowledge (Leonard 2000), making them critical for developing process innovation, which is heavily dependent on tacit and systematic knowledge (Gopalakrishnan, Bierly, and Kessler 1999). In this way, external search depth offers a firm direct and repeated access to its partner's organizational mechanisms and operations, reducing its potential confusion about the partner's technology and enhancing the efficiency of the transformation and exploitation of related knowledge (Phelps 2010). The ongoing business and social interactions that characterize search depth make it more aligned, relative to search breadth, with the transfer of tacit and routine-embedded knowledge (Teece 1992).

Furthermore, search depth can ease the development of trust and reciprocity between partners, which reduces uncertainty, contractual hazards, and the potential for misinterpretation of newly-acquired knowledge (Phelps 2010). Search depth can thus mitigate knowledge asymmetries between partners, as it "reduces the extent to which alliance partners protect

knowledge, increases their willingness to share knowledge, and increases interfirm learning and knowledge creation" (Karamanos 2012, p. 77).

Developing deep, trust-based relationships with external partners takes time, but is especially important for firms operating in a relatively extreme context. There are reasons to believe that such firms can benefit from a focus on search depth; scholars have emphasized that trust and informal commitment, developed over time, are key to the exchange of knowledge in environments characterized by political and economic uncertainty (e.g., Wasti and Wasti 2008; Morgan and Hunt 1994). Discussions with Iranian managers in the automotive industry support this assertion. Iranian firms had been engaged in deep collaboration with foreign automakers since 1980. After the intensification of sanctions in 2012, most foreign firms were prohibited from exchanging knowledge with their Iranian partners (Business Monitor International, 2015). However, the long collaborations had created some strong, trust-based relationships, which reduced uncertainty and facilitated the transfer of tacit knowledge. In some cases, the partner firms were even able to establish communication channels through third-party partners, to enable limited sharing of ideas despite the sanctions.

Considering the theoretical lens of the attention-based view (Ocasio 1997), SME managers often operate with limited resources, making them more prone to concentrating on those relationships that create valuable ideas, particularly with partners who exchange critical and tacit knowledge. Through deep relationships and monitoring of outcomes, firms should be better positioned to assess different sources, identify those that provide stronger, more useful solutions, and allocate more resources to key sources (Terjesen and Patel 2015). In this way, through collaborating deeply with a limited number of external partners, the firm has the potential to acquire and exploit the new technological ideas that are critical for developing process innovation. According to the above discussion, we hypothesize:

Hypothesis 2: *External search depth is positively related to the development of process innovation in SMEs.*

2.3. The Mediating Role of Absorptive Capacity

There is an extensive body of literature on the role of external knowledge search in the context of product innovation (e.g., Laursen and Salter 2006). However, the impact of external linkages on process innovation has been the subject of rather little attention, and the limited empirical work has yielded broadly inconclusive results. For instance, Reichstein and Salter (2006) find that firm openness has both positive and negative impacts on process innovation. Un and Asakawa (2015) indicate that only knowledge search from universities and suppliers is associated with the development of manufacturing operations. Terjesen and Patel (2015) find that search depth and breadth have both positive and negative impacts on process innovation, while Schuster and Brem (2015) report no significant relationship between external collaboration and process-related innovation activities.

One possible explanation for these contradictory outcomes might be related to the fact that successful utilization of external sources requires firms to have capabilities that enable them to identify, transform, and apply novel ideas into their existing systems, such as production lines (Aliasghar, Rose, and Chetty 2019a; Lewin, Massini, and Peeters 2011). As Lichtenthaler (2011, p. 88) asserts, "managers have to acknowledge the need to develop organizational capabilities to successfully manage open innovation".

This leads to a consideration of absorptive capacity (AC), which Cohen and Levinthal (1990, p. 128) define as "the firm's ability to recognize the value of new, external information, assimilate and apply it to reach the organization's goals". The concept of AC thus plays a key role in understanding the exploitation of external knowledge. Lane, Koka, and Pathak (2006) and Zahra and George (2002) re-conceptualize AC and discuss its multidimensional nature, which is not adequately represented using a single operational measure such as R&D intensity

(Volberda, Foss, and Lyles 2010). Emphasizing the multidimensionality, Lane, Koka, and Pathak (2006, p. 856) define AC as "a firm's ability to utilize external knowledge through the sequential processes of exploratory, transformative, and exploitative learning", and note that the various dimensions have different influences on innovation-related outcomes. Acquiring external knowledge represents exploratory learning, which pertains to the concept of potential absorptive capacity (PAC) (Zahra and George 2002); maintaining knowledge over time represents transformative learning. On the other hand, the utilization of newly-acquired knowledge reflects exploitative learning, which pertains to the notion of realized absorptive capacity (RAC) (Zahra and George 2002). AC can be viewed as a two-phased dynamic capability (Zahra and George 2002), where PAC is a firm's capability for acquiring and understanding external knowledge, while RAC is the ability to integrate and apply newly-acquired knowledge.

AC is important for all firms, but especially for those operating in extreme contexts, such as Iran under sanctions. Given limited access, a key challenge for firms is to be able to recognise and make use of potential – albeit constrained – sources of knowledge that may assist them in developing and retaining their competitive positions. These firms are under pressure, from customers and the government, to improve both their production levels and the quality of their output. The challenges associated with access may mean that the newly-acquired knowledge is fragmented, making it more difficult to apply for immediate exploitation (Winter 1984; Aliasghar, Rose, and Chetty 2019a). Having internal mechanisms and routines in place to facilitate the ability to benefit from external knowledge (Lewin, Massini, and Peeters 2011; Zahra, and George 2002) thus seems particularly important for firms operating in an uncertain environment.

While some studies have focused on the potential costs and benefits of external knowledge search, with respect to innovation outcomes (Laursen, and Salter 2006), there

remains a lack of understanding about the extent to which AC mediates the relationship between knowledge search and process innovation, despite the fact that some critical research in this field (e.g., Zahra and George 2002; West and Bogers 2014) highlights that the firm's AC specifies the extent to which it is able to apply newly-generated knowledge. On this basis, we hypothesize:

Hypothesis 3: *A firm's absorptive capacity mediates the relationship between external knowledge search (i.e., depth and breadth) and process innovation in SMEs.*

2.4. Innovation and Performance

Relative to product innovation, developing process innovation is viewed as more challenging and resource-consuming, and takes longer to exploit (Terjesen and Patel 2015). However, the challenge can be worthwhile; Lee, Lee, and Garrett (2017, p. 509) note that "the benefits of process innovation are organized as productivity gains, improvements in product quality, and cost and time savings". Previous research provides evidence that process-related innovation activities are positively associated with performance, including sales growth and profit margins (He and Wong 2004; Piening and Salge 2015). Process innovation has been found to assist firms in reducing the price of products by increasing productivity and improving supply chain technologies, leading to increased customer satisfaction and improved sales (Li 2005). Given SMEs' resource limitations, they are arguably under relatively more pressure to utilize their resources effectively in order to enhance productivity. Process innovation, which "can stretch resources, may reduce optimal size, and facilitate learning curve effects" (Wolff and Pett 2006, p. 272) would thus seem to be especially important for SMEs. Therefore, we hypothesize:

Hypothesis 4: *Process innovation is positively related to performance for SMEs.*

Figure 1 provides a graphical representation of our four hypotheses.

[Figure 1 goes about here]

3. Research Method

3.1. Sample and Data Collection

We test our hypotheses using a sample of SMEs that are part of the Iranian automotive industry's value chain. The automotive industry is Iran's largest, after oil, and among the leading automobile manufacturers, in terms of volume, in the Middle East and North Africa (MENA) region. The industry's annual turnover was nearly 12 billion USD and it was responsible for 1.2% of the world's vehicular production (Business Monitor International 2015).

While the Iranian automotive industry has substantial size, the quality of its products is not of international standards. Following the international sanctions imposed in 2011, car production dropped by approximately two thirds, and prices increased dramatically (Business Monitor International 2015). Faced with the need to catch up, and generally lacking the resources necessary for internal R&D, Iranian managers in this industry have strong incentive to search externally for technological ideas, to enhance their process innovation and, consequently, their competitive advantage in the limited international markets to which they have access (Ghazinoory, Divsalar, and Soofi 2009). Iran's 2025 economic vision includes, as a high priority, the goal of reaching "the number one ranking in the automotive industry of the region, 5th ranking in Asia and 11th ranking in the world" (Business Monitor International 2015, p. 10). Thus, it is important to understand how, and under what conditions, SME suppliers to the Iranian automotive industry can absorb knowledge from partners in order to develop their operations (Aliasghar, Rose, and Chetty 2019b; Tajeddini and Trueman 2016).

The automotive industry in Iran can be reasonably be described as medium-tech. While there is no universally-accepted definition of what constitutes a high-tech industry, there is a general agreement on some common characteristics, such as high R&D intensity; designing, developing, and introducing innovative and technologically advanced products; strong usage of state-of-the-art technology and methods of production; and a large proportion of highly-

skilled and technology-oriented workers, such as scientists, engineers, and technicians (e.g., Decker, Haltiwanger, Jarmin, and Miranda 2016; Hecker 1999; Hecker 2005). The bulk of the SME suppliers operating in the Iranian automotive industry are not well-described by such characteristics, but neither are most well-described as low-tech.

Our data were collected from SMEs that form part of the Iranian automotive supply chain. The survey instrument was designed in English, translated into Farsi, then back-translated, using bilingual native Farsi speakers. The questionnaire was constructed by drawing on the extant literature, with some items modified for clarity following interviews with 16 managers in the Iranian auto industry. Pre-testing with senior managers (e.g., R&D managers) was also undertaken, to ensure that the questions were understandable and appropriate.

During the interviews, it became clear that there are approximately 250 firms that are viewed as playing key supplier roles in the Iranian automotive industry; not all qualify as SMEs. We contacted the managers of these each of these 250 firms by telephone and email, inviting them for a face-to-face meeting during which time the questionnaire would be completed. A total of 200 suppliers agreed to participate in this research; we received 171 completed surveys, for a 68% overall response rate. In this paper, we use a subset of the sample, consisting of the 124 responding firms that qualify as SMEs by virtue of reporting fewer than 200 full-time-equivalent employees. (The sample sizes used for the modelling are somewhat smaller, due to missing data.)

3.2. Measurement

Performance: Following previous studies (Aliasghar, Rose, and Chetty 2019a; Reinartz, Krafft, and Hoyer 2004; Wiklund and Shepherd 2005), we measured performance based on growth and goal attainment, asking respondents to evaluate their firm's performance during the previous year, relative to their competitors, in terms of profit growth, return on assets, sales

growth, market share growth, and cash flow; the Cronbach's α for this five-item factor was 0.89.

Process innovation: Process innovation is defined as "the application of new or significantly improved elements into an organization's production or service operations with the purpose of accomplishing lower costs and/or higher product quality" (Kim, Kumar, and Kumar 2012, p. 297). Consistent with previous studies, we operationalized process innovation using six items (Kim, Kumar, and Kumar 2012); α= 0.89.

Absorptive capacity: Previous empirical studies have tended to operationalize AC as a unidimensional construct (Lim 2009), which risks oversimplifying the complex nature of this concept (Zahra and George 2002). We operationalized AC as a multidimensional construct, following the definition by Zahra and George (2002); see also Aliasghar, Rose, and Chetty (2019b). Potential AC was measured using 12 items, with α=0.95 (Volberda, Foss, and Lyles 2010; Jansen, Van Den Bosch, and Volberda 2005), and our measure of realized utilized six items, with α=0.91 (Jansen, Van Den Bosch, and Volberda 2005)[1].

Knowledge search breadth and depth: Building on previous studies (e.g., Laursen and Salter 2006), external search breadth was operationalized as the number of types of external sources with which the firm reported having a relationship. The survey instrument incorporated 11 potential knowledge sources, including universities, suppliers, customers, and R&D providers. The search breadth measure can thus assume values from 0 (no external collaboration) to 11 (collaboration with all 11 potential types of partners).

Following Laursen and Salter (2006), search depth was operationalized by asking "What is the importance of cooperation with the external partners (e.g., supplier, competitor, university, customers) in your firm's innovation activities?", with responses based on seven-

[1] In this study, absorptive capacity was measured as a second-order construct.

point Likert scales in which 1 represented "low importance" and 7 "high importance".[2] Similar to the approach taken in previous studies (e.g., Ferreras-Méndez, Newell, Fernández-Mesa, and Alegre 2015), we dichotomized the responses associated with each of the 11 types of potential knowledge sources, treating responses of 5-7 and 1-4 as reflecting deep and not very deep collaboration, respectively, with external partners. Summing across the 11 partner types yields a search depth measure that can assume values between 0 (minimal depth) and 11.

3.2.5. Control variables: We accounted for several attributes that may be expected to contribute to explaining our dependent variables. First, we controlled for in-house R&D investment using the number of employees involved in R&D divided by the total number of employees (e.g., Aliasghar, Rose, and Chetty 2019a; Cohen and Levinthal 1990). We also controlled for the age of the firm, on the basis that older firms have more experience, and potentially more resources; more extensive resources may allow firms to purchase, for example, new machinery that contributes to process of innovation. We also distinguished between private and public ownership, as publicly-owned firms may have additional resources due to governmental support. Finally, we controlled for product innovation, which was operationalized using a five-item scale with α=0.85 (Kim, Kumar, and Kumar 2012; Subramaniam and Youndt 2005)

The correlation matrix and descriptive statistics for the variables used in the modelling are shown in Table 1.

[Insert Table 1 here]

3.3. Reliability and Validity

We examined the reliability and validity of the constructs using Smart PLS, prior to testing the hypotheses (Chin 1998; Henseler, Ringle, and Sinkovics 2009). Reliability was assessed

[2] This measure, while established, is imperfect, as it does not allow for a distinction between "the cases which have a very deep linkage with one or two specific external sources from companies whose relationships are not so deep but are sustained with more external sources" (Ferreras-Méndez, Newell, Fernández-Mesa, and Alegre 2015, p. 5).

through Cronbach's α values and composite reliabilities (CRs). As seen in Table 2, the Cronbach's α and CR values are all higher than 0.70, suggesting acceptable reliability (Fornell and Larcker 1981). With the values of the average variance extracted (AVE) all exceeding 0.50, we also find support for convergent validity. In addition, the squared correlations between the constructs are lower than the AVEs, which indicates discriminant validity (Fornell and Larcker 1981).

[Insert Table 2 here]

To evaluate the predictive ability of the structural model, we considered the Stone-Geisser Q^2 statistic (Geisser 1974). A Q^2 score that is greater than zero suggests that the explanatory variables that form the latent variable are relevant with respect to prediction (e.g., Aliasghar, Rose, and Chetty 2019b). As shown in Table 3, this threshold criterion is met for our three latent variables, indicating predictive relevance.

[Insert Table 3 here]

4. Analysis

Since the data for explanatory variables and dependent variables were obtained from the same respondent, we undertook several approaches to minimizing the potential for common method bias (Podsakoff, MacKenzie, Lee, and Podsakoff 2003). First, in addition to the anonymous nature of the questionnaire, the items employed for the dependent and explanatory variables were placed in different sections of the survey instrument. Second, an extensive pilot study process ensured that the questions in the survey were understandable for the respondents. Third, the respondents were mainly (82%) senior-level managers, with the knowledge necessary to respond to the questions, and the survey results were quite consistent with the findings from interviews with 16 managers, providing further evidence that our findings are not influenced by common method bias. Finally, we undertook *post-hoc* analysis using Harman's single-factor

test; the results revealed a poor fit, with no single factor accounting for more than 27% of the variance.

As we utilized ordinary least squares regression modelling for the hypothesis testing, we assessed the potential for multicollinearity in the regression models, considering variance inflation factors (VIFs). The VIF values in our models were all less than 2, showing no evidence of problem multicollinearity. Residual analysis revealed no problems with model assumptions such as heteroscedasticity.

To test for the hypothesized mediation, we used a four-step approach, following Baron and Kenny (1986). According to this approach, in the context of our study, mediation is supported when: (1) the relationship between external knowledge and process innovation is significant, (2) the relationship between the external search and AC (the proposed mediator) is significant, (3) the relationship between AC and process innovation is significant, and (4) the relationship between AC and process innovation is significant when controlling for the explanatory variables.

The results of regression analyses are shown in Table 4. Models 1 and 2 have absorptive capacity as the dependent variable, while Models 3-5 have process innovation as the dependent variable. Performance is the dependent variable for Model 6. Model 1 provides a baseline, including only the control variables: R&D intensity, age, ownership, and product innovation.

Model 3 is used to test Hypotheses 1 and 2, regarding the relationships between process innovation and the depth and breadth of external knowledge search. Knowledge search breadth is positively and significantly (p<0.001) related to process innovation, contradicting Hypothesis 1 but satisfying the first condition of the mediation analysis. However, the coefficient associated with knowledge search depth is not significant; therefore, neither Hypothesis 2 nor the mediation (Hypothesis 3, with respect to search depth) is supported by our data.

We address the second condition for the mediating effect of AC on the relationship between search breadth and process innovation in Model 2. The positive and significant (p<0.05) coefficient associated with search breadth satisfies the condition. The third mediation condition is demonstrated in Model 4, where AC has a significant relationship with the development of process innovation (p<0.001).

Model 5 is used to assess the last of the mediation conditions. The coefficient associated with AC is positive and significant (p<0.001) when the two external search variables are included in the model. This provides evidence that AC has a mediating effect on the relationship between external search breadth and process innovation. The fact that the estimated coefficient for search breath is significant in Model 5, but smaller than the estimated coefficient in Model 3, suggests that the mediation is partial. Therefore, Hypothesis 3 is partly supported.

Finally, the results shown in Model 6 show evidence of a positive and significant (p<0.001) relationship between process innovation and the firm's performance. This result provides support for Hypothesis 4.

[Insert Table 4 here]

Further support for the observed mediation is found by considering effect sizes, using the Cohen (1988) f^2 value. Cohen (1988) notes that values of 0.02, 0.15, and 0.35 indicate small, medium, and large effects, respectively. As indicated in Table 5, the effect size analysis provides evidence that the relationship between external search and process innovation is mediated by AC, given that the AC-process innovation relationship has a large (f^2 = 0.37) effect size, in comparison with the others.

[Insert Table 5 here]

5. Discussion

Since Chesbrough (2006) introduced the notion of open innovation, many empirical studies have found evidence that firms' openness to the external environment can improve innovation. However, the current stock of published research has focused primarily on product innovation (Brunswicker and Vanhaverbeke 2015; Katila and Ahuja 2002), generally in the context of large, high-tech companies located in developed economies. We still know very little about the impact of open innovation on lower-tech SMEs, especially those operating from the challenging institutional environments that characterize emerging and developing markets (Hossain and Kauranen 2016). Scholars have long acknowledged that SMEs are not simply smaller versions of large organizations (e.g., Sadeghi, Rose, and Chetty 2018; Lu and Beamish 2006; Lu and Beamish 2001); the process and outcomes associated with applying open innovation are likely to differ between SMEs and larger firms, as SMEs are typically subject to resource scarcity, less-structured technology processes, and more constrained innovation capabilities (Lichtenthaler 2008).

Contrary to our expectations, the data provide no evidence of a significant relationship between external search depth and the development of process innovation, marginal to the other variables in the model. This finding stands in contrast to the prevailing view in the existing literature, which pertains mainly to product innovation; we would have expected search depth to have been even more important in process innovation, given its more tacit nature (e.g., Terjesen and Patel 2015). A possible explanation for these unexpected findings may be the time-consuming and resource-intensive nature of developing and maintaining deep and intense relationships with external partners, which requires managerial attention, as well as human and financial resources (Laursen and Salter 2006). Resource-constrained SMEs may be less able to nurture such deep partner relationships.

Another potential explanation for this seemingly counter-intuitive finding may be context-driven. For decades, Iranian firms have been operating in a business environment

characterized by strict international sanctions, and unfavourable and volatile macro- and micro-economic conditions. This environment imposes a high level of uncertainty in the market, which may push Iranian managers towards concentrating more on short-term relationships with external partners, in the hope of achieving quick returns. In response to such constraints, the priority of many Iranian managers has shifted towards fighting to survive in a hostile environment and focusing on process innovation. In such an extreme context, there is a risk that firms will become more short-term oriented and focused on survival, making them reluctant to dedicate the time and resources needed to build and maintain deep, long-term relationships (Heirati, O'Cass, Schoefer, and Siahtiri 2016). In this regard, our empirical finding underscores the crucial role of environmental turbulence on shaping firms' strategies related to searching for knowledge and developing process innovation.

Although this research has been conducted in the context of Iran, a country that operates under an extraordinary situation, our findings have potential implications for firms based in other countries, particularly in times of crisis. Iran's current business environment makes it what Hällgren, Rouleau, and De Rond (2018) refer to as an extreme context. Being extreme, however, does not mean non-generalizable[3]. In this light, our findings suggest that firms operating in environments that are volatile and particularly challenging (e.g., Russia, Cuba, Belarus, some African countries) may need to pay extra attention to the breadth of their knowledge search in order to develop their manufacturing processes, while being cautious about investing too heavily in search depth, when working toward process-related innovation.

Furthermore, our results suggest that AC mediates the relationship between search breadth and process innovation, but not search depth. The weak results with respect to search depth may be explainable on the basis that maintaining deep relationships with partners requires specific internal mechanisms and routines that may not be readily transferable. As

[3] We are grateful to an anonymous referee for making this point.

Hsieh, Ganotakis, Kafouros, and Wang (2018, p. 656) note, "the mechanisms to aid collaboration with a given type of partner are context-specific and cannot always be used for other partner types". Firms that collaborate intensively with multiple external sources may find it difficult to combine and integrate deep knowledge obtained from inherently different sources and effectively leverage it to improve performance.

Our empirical findings reinforce the notion that it is important for firms to build AC as a dynamic capability that assists in the acquisition and understanding of external knowledge, along with the development of internal mechanisms and routines that support external collaboration. This is consistent with the argument of Lewin, Massini, and Peeters (2011), that AC metaroutines help the firm to develop a platform for better and more efficient communication and coordination – intra- and inter-organizational – and create a shared context that facilitates knowledge exchange (Un, Cuervo-Cazurra, and Asakawa 2010). This highlights the importance of developing mechanisms and routines, particularly for firms operating under disrupted contexts and uncertainty, to identify new technological ideas and enable firms to bring external information back to their organizations effectively, especially when the firms have relationships with many partners (Lewin, Massini, and Peeters 2011). Simple knowledge acquisition may not lead to successful exploitation; rather, firms need to design and implement strategies and mechanisms in order to benefit effectively from their external collaborations.

In addition, despite the expectation based on prior literature, our analysis did not provide any evidence of a significant relationship between product innovation (which we included as a control variable) and performance. This may be partly attributable to the context of the study. Following the imposition of sanctions, Iran's domestic car production dropped dramatically, while some foreign competitors that still had access (e.g., Chinese manufacturers) increased their presence and market shares in Iran by offering higher-quality vehicles at lower prices. This development would clearly have provided Iranian automotive firms with strong

motivation to obtain the capabilities required to improve their product quality and regain their domestic competitive positions (Aliasghar, Rose, and Chetty 2019b), but it appears that such efforts have not led to improved performance. Our results reinforce the importance of considering the context in which firms operate; different external environments mean that the results of studies conducted in developed countries may not be directly applicable to emerging or developing contexts. As a dynamic and evolving phenomenon, the impact of innovation cannot be understood in isolation from factors related to the firm's environmental, institutional, and macro-economic situation.

6. Conclusion

Despite the growing need for improving manufacturing productivity, process innovation has received rather little attention in the innovation management literature, leaving some important questions unanswered (Schroeder, Linderman, Liedtke, and Choo 2009). This also raises concerns about the applicability of many prior findings to the process innovation of SMEs operating under disrupted contexts and severe uncertainty, including the restricted access to international supply chains that has taken place due to the current pandemic. Our study of SMEs in the Iranian automotive industry thus contributes to the understanding of the nature of process innovation by shedding light on factors that may assist SME managers operating in extreme contexts to enhance it, along with understanding more about its associated performance implications.

This study also contributes to the literature on innovation and AC, by theorizing about and testing the relationship between a firm's openness and its development of process innovation. More specifically, we provide new insight into how the depth and breadth of external knowledge search have different impacts on process innovation, in the context of a mature industry in an emerging and constrained economy. We find evidence that AC plays a

critical role in transforming firms' externally-sourced knowledge into process innovation and, consequently, performance.

7. Managerial Implications

From a managerial perspective, the pursuit of process innovation entails SMEs' searching for new knowledge that has the potential to enhance operational success. One way to approach this is by seeking to learn from external partners, such as suppliers, competitors, and universities. Of course, obtaining knowledge from different external sources will not necessarily lead to process innovation. While we have found evidence that broad knowledge is a positive factor in the development of process innovation, SMEs also need to focus on AC; the associated internal mechanisms and routines are important in order to facilitate the transformation of externally-generated knowledge into process innovation.

External knowledge search breadth can facilitate access to a variety of new knowledge and customer solutions (Hargadon and Bechky 2006). SMEs have the opportunity to enhance their competitive positions by developing and implementing search strategies that offer synergies with each firm's AC. Finally, our study highlights the importance for SMEs that are operating under institutional limitations to search for novel ideas outside of their own boundaries, in order to become process innovators.

8. Limitations and Directions for Future Studies

While this paper sheds light on how SMEs develop process innovation through openness, our study is subject to some limitations that create opportunities for future research. First, our data are cross-sectional, allowing us to explore the relationships at one time, but not through time. To develop a deeper understanding of what is arguably a dynamic issue, longitudinal studies are needed. Second, while we focus on SMEs in the Iranian automotive industry, which represents a specific context that has rarely been studied in the internationally-accessible literature, it would be interesting to explore firms that are situated in other industries and

geographical contexts. Despite the extreme nature of the Iranian context, our findings should offer insights into firms in other nations subject to some degree of isolation (e.g., Russia, Egypt) or disruption (currently a global issue). Third, future studies may explore how external collaboration is related to the development of other types of innovation (e.g., administrative) in addition to generating deeper understanding regarding process innovation.

Fourth, there is scope for additional research pertaining to measurement. For example, to enhance validity, we followed common practice and adopted an existing scale for measuring external search depth (Laursen and Salter 2006; Ferreras-Méndez, Newell, Fernández-Mesa, and Alegre 2015). However, this scale does not allow us to fully examine the complexity of this phenomenon, including the length of the firm's collaboration with external partners.[4] We encourage future researchers to improve on the operationalization of external knowledge search depth by incorporating this and other aspects of how firms interact with their external sources for knowledge acquisition. Furthermore, the existing measures for product and process innovation (Kim, Kumar, and Kumar 2012; Subramaniam, and Youndt 2005; Valle, and Vázquez-Bustelo 2009; Jansen, Van Den Bosch, and Volberda 2006) are rather difficult to compare to each other, as the operationalization of product innovation pertains largely to innovativeness (scope and frequency of innovation). Future work might also explore how different search strategies affect radical and incremental process innovation.

Fifth, additional research is needed, to explore the impacts that market and technological turbulence have on SMEs' knowledge search strategies and process innovation. In this study, we have investigated the roles of search strategies on process innovation; further studies may explore the impact of SMEs' outbound knowledge exchange on process-related innovation activities. Under the assumption that SMEs are likely to suffer from resource

[4] We are grateful to an anonymous referee for making this point.

limitations, future research is needed to investigate how organizational and industrial factors facilitate or impede managers, with respect to embracing open innovation.

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Figure 1: Research Model

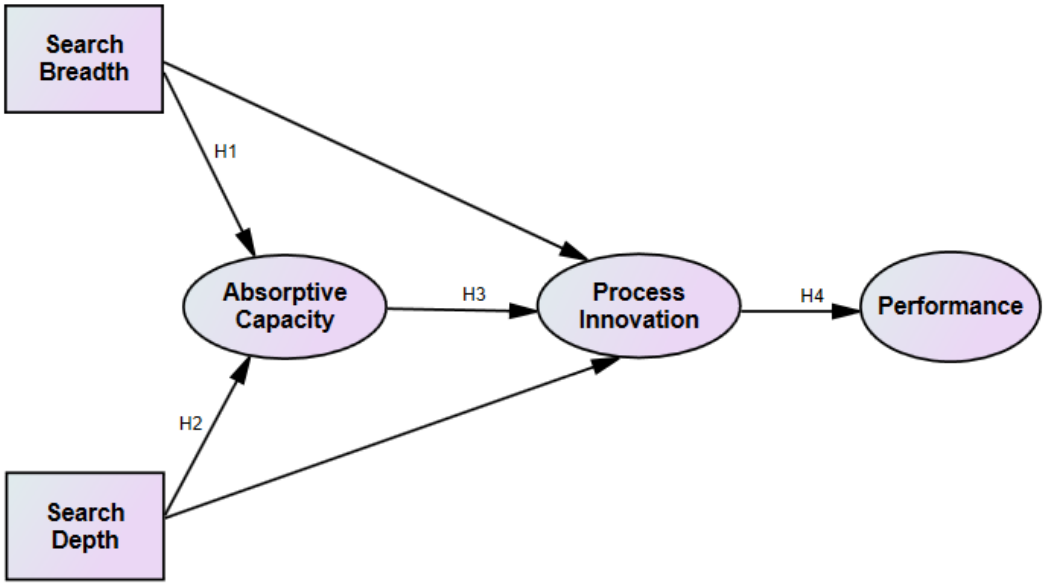

Table 1: Correlations, means, and standard deviations.

	Mean	S.D	1	2	3	4	5	6	7	8	9
1. Performance	4.06	1.26	**0.70**								
2. Process innovation	4.46	1.16	0.46**	**0.70**							
3. Search breadth	8.90	2.21	0.35**	0.52**	1						
4. Search depth	2.67	2.96	0.04	0.30**	0.36**	1					
5. Absorptive capacity	4.18	1.08	0.41**	0.62**	0.36**	0.38**	**0.50**				
6. Ownership	0.91	0.28	-0.01	0.10	-0.02	0.10	-0.01	1			
7. R&D intensity	1.68	1.19	-0.04	0.20*	0.07	0.19*	0.14	0.13	1		
8. Age of the company	19.28	10.63	-0.26*	-0.40**	-0.31**	-0.08	-0.22	-0.12	-0.13	1	
9. Product innovation	3.50	1.14	0.23*	0.36**	0.22*	0.32**	0.37**	0.16	0.18*	-0.09	**0.62**

"Note: Diagonal elements in bold represent the square root of the average variance extracted (AVE)".

n=124

$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.00$

Table 2 Factor loadings, Cronbach's α, and validity assessment	Factor Loading	α
"Absorptive capacity" (CR=0.95, AVE=0.50)		**0.93**
"Potential absorptive capacity" (CR=0.95, AVE=0.63)		**0.95**
"Our company observes external sources of new products and technologies in detail".	0.73	
"Our company frequently scans the environment for new technologies".	0.79	
"Our company thoroughly observes technological trends".	0.81	
"Our company has information on the state-of-the-art of external technologies within our industry".	0.82	
"Our company regularly utilizes new opportunities in the new market.	0.81	
Our company collects industry information (e.g., potential competitors, customer needs, etc.)".	0.74	
"Our employees regularly approach the external environment (e.g., universities, research institutes, foreign firms, government, etc.) to acquire technological knowledge".	0.76	
"Our company periodically organizes special meetings with external partners to acquire new technologies".	0.80	
"Our company quickly understands new opportunities in our market (e.g., emerging customer needs)".	0.74	
"Our company quickly analyses and interprets changing market demands (e.g., shifting structure of competition)".	0.72	
"Our company quickly analyses and interprets new technology trends".	0.77	
"Our employees store technological knowledge for future reference".	0.70	
"Realized absorptive capacity" (CR=0.93, AVE=0.68)		**0.91**
"New opportunities to serve our customers with existing technologies are quickly understood".	0.83	
"Our company regularly matches new technologies with ideas for new products".	0.84	
"Employees share practical experiences".	0.81	
"We grasp the opportunities for our firm from new external knowledge".	0.70	
"Our company regularly applies technologies in new products".	0.82	
"Our company considers how to better exploit technologies".	0.76	
"Process innovation" (CR=0.92, AVE=0.70)		**0.89**
"Our company has introduced new or significantly improved machinery and equipment for producing products or services".	0.76	
"Our company has introduced new or significantly modified processes for producing products or services".	0.82	
"Our company has introduced new or significantly improved information technologies for producing products or services".	0.90	
"Our company has introduced technological improvements in supply, storage, or distribution systems for manufactured products".	0.83	
"Our company has introduced technologically new or significantly improved methods of producing manufactured products".	0.85	
Performance (CR=0.92, AVE=0.70)		**0.89**
"Profit growth"	0.81	
"Return on assets"	0.85	
"Sales growth"	0.84	
"Market share growth"	0.86	
"Cash flow"	0.84	
Product innovation (CR=0.89, AVE=0.62)		**0.85**

Table 2 Factor loadings, Cronbach's α, and validity assessment	Factor Loading	α
"Our new products differ substantially from our existing products".	0.71	
"Our company introduces new product and service innovations into the market more frequently than our competitors".	0.85	
"Our company commercializes products and services that are completely new to our firm".	0.85	
"Our company is well known by our customers for our new product and services".	0.78	
"Our company regularly uses new opportunities in new markets".	0.75	

Table 3: Inner model evaluation indicators.

Factor	Q^2
Process innovation	0.30
AC	0.45
Performance	0.15

Table 4: *Results of regression analysis*

	Absorptive capacity			Process innovation		Performance
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	3.13	1.90	1.67	2.01	0.84	2.36
Control variables						
R&D intensity	0.01	-0.01	0.01	-0.01	-0.01	-0.11
Age of the company	-0.01*	-0.01	-0.03**	-0.03***	-0.02**	-0.01
Ownership	-0.01	0.16	0.32	0.17	0.19	-0.08
Product innovation	0.37***	0.37***	0.27**	0.11	0.16	0.04
Key predictors						
Search breadth		0.10*	0.23***		0.16***	
Search depth		0.06	-0.01		-0.03	
Absorptive capacity				0.60***	0.49***	
Process innovation						0.46***
R^2	0.19	0.28	0.38	0.50	0.54	0.24
Adjusted R^2	0.15	0.23	0.34	0.47	0.50	0.20
***F* value**	5.29	5.54	9.25	18.00	13.80	6.03
Max VIF	1.09	1.18	1.18	1.26	1.40	1.35
n	96	90	95	96	90	99

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

Table 5: *Effect sizes*

Effect	R^2 **included**	R^2 **not included**	f^2
Search breadth → Process innovation	0.51	0.46	0.12
Search depth → Process innovation	0.51	0.51	0.00
AC→ Process innovation	0.51	0.34	0.37