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Where to search for process innovations? The mediating role of absorptive capacity and its impact on process innovation

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Abstract: While the potential of open innovation to develop product-related improvements through the use of external knowledge sources is undeniable, our understanding of how firms become process innovators remains limited. Distinguishing between product and process innovation is important, as insights gleaned from investigating product innovation may not relate directly to the study of process innovation. This study provides new insight into open innovation and absorptive capacity by proposing the mediating role of absorptive capacity – potential and realized – on the relationship between knowledge search from external sources and process-related innovation activities. We test our model using a sample of 171 auto component suppliers in Iran, and find evidence that the learning effects of external scanning increase when a firm learns how to better manage external searches in terms of external absorptive capacity routines. Our results indicate that, while knowledge search from value chain partners is related to process innovation, knowledge search from universities and other research organizations is not, and that potential absorptive capacity mediates the relationship between external knowledge search and process innovation. These findings shed further light on the relationship between a firm's openness and its process innovation.

Keywords: open innovation, process innovation, universities and research organizations, value chain partners, potential and realized absorptive capacity

1. Introduction

The concept of open innovation has grabbed substantial attention and interest among scholars and policymakers in recent years. Research in the broad fields of marketing and management has supported the idea that engaging with external sources leads to a number of benefits, such as the sharing of capabilities and risks between partners, and assists firms to develop innovation and higher profits (Katila & Ahuja, 2002; Chesbrough, 2003; Laursen & Salter, 2006).

Yet, despite its popularity, the open innovation literature has concentrated mainly on *product* innovation (e.g., Ferreras-Méndez, Newell, Fernández-Mesa, & Alegre, 2015; Laursen & Salter, 2006). In contrast, research on how firms' knowledge search can develop *process* innovation remains limited (Keupp, Palmié, & Gassmann, 2012; Tsinopoulos, Sousa, & Yan, 2017). Process innovation is a critical factor in expanding a firm's competitive advantage, given its potentially profound impact on developing performance by decreasing costs (Bernstein & Kök, 2009), and enhancing quality (Terziovski & Guerrero-Cusumano, 2009) and flexibility (Reichstein & Salter, 2006). The differences between product- and process-related innovation, with respect to the innovation itself, its evaluation, and its potential impact on competitive advantage, means that findings pertaining to product innovation may not be directly applicable to process innovation (Un & Asakawa, 2015).

Compared to product innovations, process innovations are more difficult to reverse-engineer (James, Leiblein, & Lu, 2013), take longer to develop (Damanpour & Gopalakrishnan, 2001), and are tacit and systematic in nature (Terjesen & Patel, 2015). Developing process innovation means that firms may require capabilities that allow them to acquire, assimilate, and exploit knowledge – often externally-generated – in order to improve their manufacturing processes and operations; this is often referred to as "absorptive capacity" (e.g., Cohen & Levinthal, 1990; Zahra & George, 2002).

In this paper, we focus on firms operating in the mature automotive industry, and ask the following question: How do these firms foster process innovation by tapping into outside sources of knowledge? In addressing this question, we contribute to the literature in three ways. First, despite substantial interest in the link between open innovation and firm-level product innovation (e.g., Köhler, Sofka, & Grimpe, 2012; Sofka & Grimpe, 2010), few studies have examined the potential mediating effect of both potential and realized absorptive capacity (AC) on the relationship between external search and process innovation. Second, given that

different types of external sources possess different knowledge and abilities, managers need to find appropriate partners for the specific knowledge that they seek (Chen, Chen, & Vanhaverbeke, 2011). We extend the open innovation literature by proposing and testing a model pertaining to how searching for knowledge from value chain partners (e.g., customers, competitors, and suppliers) and universities and/or research organizations is associated with the development of process innovation, responding to the call from Terjesen and Patel (2015) for more research on the relationship between knowledge search and process innovation.

Finally, most of our understanding about the relationship between a firm's openness and its innovation outcomes is based on research conducted in developed countries (Terjesen & Patel, 2015). It is also important to explore these concepts in the context of countries characterized by market conditions that differ from those in more advanced economies. In addition, evidence to support the concept of open innovation has been found almost exclusively in studies of high-technology industries such as pharmaceuticals and chemicals (e.g., Ferreras-Méndez et al., 2015); the applicability of the concept in more mature and lower-technology industries remains an open question (Schuster & Brem, 2015).

In this paper, we study open innovation, absorptive capacity, and process innovation in the context of a mature industry in an emerging economy, focusing on small- and medium-sized enterprises (SMEs) operating in the Iranian automotive sector. Lazzarotti, Manzini, Pellegrini, and Pizzurno (2013, p. 53) describe the automotive industry as "an industry trapped by cost and innovation pressure by customers". While the Iranian context has some specific attributes, due to long-term international sanctions, the findings of our study can also shed light this relationship in firms from other countries that have been subject to trade sanctions (e.g., Russia, Cuba, Iraq, some African countries), and others for which impediments to free trade, while less severe, are still present.

The remainder of the paper is structured as follows. The next section reviews the literature, which is used to generate two hypotheses. The third section describes the research methods, the model, and variable operationalizations. The fourth section presents the empirical results obtained via structural equation modeling based on partial least squares (PLS), and the final section discusses the conclusions, managerial implications, and limitations, and suggests avenues for future research.

2. Literature review and theoretical development

In a seminal paper on the model of process development, Utterback and Abernathy (1975) define process innovation as the cumulative development of the entire (production) process, which is "the system of process equipment, workforce, task specifications, material inputs, work and information flows, etc. that are employed to produce a product or service" (p. 641). Utterback and Abernathy (1975) note that, in the early phases of an industry or product life cycle, we can expect an increase in the rate of product innovation. However, after both producers and users of a product gain experience, and the industry goes through the product life cycle, the development of dominant design begins the change to process innovation (e.g., Abernathy & Utterback, 1978; Akiike, 2013; Brem, Nylund, & Schuster, 2016).

The definition of dominant design has developed over time. Utterback (1994, p. 24) refers to it as a design that "wins the allegiance of the marketplace […] that competitors and innovators must adhere to if they hope to command significant market following". Murmann and Frenken (2006, p. 23) note that a "dominant design exists in a technological class when the majority of designs have the same technologies for the high-pleiotropy core components". Previous studies have noted that the development of dominant design imposes substantial changes on industry dynamics (Anderson & Tushman, 1990; Cabigiosu, Zirpoli, & Camuffo, 2013; Oltra & Saint Jean, 2009). For example, "competition moves from product innovation to

process innovation" (Dodgson, Gann, & Phillips, 2013, p. 149), the efficiency of production process increases, and "price competition becomes more intense" (Utterback & Abernathy, 1975, p. 641). Fujimoto (2014) notes that, when the uncertainty about designing the product declines, heavier investments in improving the entire production process become justified, and "a wave of process innovations follow (e.g., the so-called Ford system) while product innovations become less frequent" (p .10).

2.1. Product versus process innovation

While there is some overlap, there are also important distinctions between product and process innovation, and their determinants may not be identical (Un & Asakawa, 2015). Broadly, product innovation is likely to be aimed at the market and customers, while process innovation is characterized by more of an internal focus. For example, a key objective of product innovation may be the differentiation of offerings through design novelty pertaining to function, aesthetics, or customer experience[1], while process innovation may have more to do with the improvement of operational efficiency (Ettlie & Reza, 1992; Un & Asakawa, 2015; Utterback & Abernathy, 1975). While both categories of innovation can lead to increases or decreases in the selling price, process innovation arguably has stronger impact on the firm's longer-term competitiveness. The traditional assumption is that product innovation allows the firm to charge more for affected products, under the assumption that they are more innovative, relative to the competition (Un & Asakawa, 2015; Utterback & Abernathy, 1975); however, product innovation may also enable the firm to compete more effectively on price. In contrast, the competitive effect of process innovation is related to improvements in manufacturing processes (Ettlie & Reza, 1992; Reichstein & Salter, 2006). The attendant development of the

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

firm's operations has the potential to allow it to embed changes that increase quality and/or reduce expenses, enhancing its longer-term competitive advantage (Pisano & Shih, 2012).

2.2. Open innovation

The critical role of openness in the development of external knowledge was identified in early studies pertaining to firm-level capabilities and resources (Barney, 1991; Wernerfelt, 1984). For decades, in-house research and development (R&D) has been viewed as a valuable strategic asset for enhancing the firm's competitive position. However, some scholars have asserted that the "closed innovation" model is no longer sustainable, due to growth in the mobility of skilled labor, the increased availability of venture capital, and rapid changes in information and communication technology (Chesbrough, 2006). An alternative perspective to "research and develop" is that of "connect and develop" (Huston & Sakkab, 2006, p. 3). Chesbrough (2006, p. 1) introduced the term "open innovation", defining it as "… purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively". In this way, two types of open innovation are identified: *inbound* and *outbound*. Inbound open innovation refers to the use of knowledge acquired from the external environment, potentially in combination with in-house R&D, while outbound open innovation refers to the external utilization and commercialization of internally-generated knowledge and ideas (Chesbrough & Crowther, 2006)[2]. Our focus in this research is on inbound open innovation, consistent with the assertion of Laursen and Salter (2006) that searching for novel knowledge that has commercial potential is a particularly critical aspect of firms' innovation-related activities.

Research on open innovation has focused mainly on product innovations (e.g., Katila & Ahuja, 2002; Köhler et al., 2012; Laursen & Salter, 2006), with relatively less written about

[2] A third form of open innovation model, the "coupled process", is a combination of inbound and outbound, and was identified by Gassmann and Enkel (2006).

how managers can develop process-related innovations through firm openness (Keupp et al., 2012). According to Reichstein and Salter (2006, p. 653), "Process innovation has often been considered a second-order innovative activity, a rather dull and unchallenging cousin of the more glamorous product innovation". That said, process innovations may be more effective than product innovations, in terms of developing competitive advantage; their intangibility and embeddedness makes them more difficult for competitors to imitate (Gopalakrishnan, Bierly, & Kessler, 1999). At the macro level, process innovation is considered to be a primary source of economic development (e.g., Hollander, 1965; Terjesen & Patel, 2015) and a core element of efficiency development, which can have a positive impact on gross domestic product growth (Mankiw, Romer, & Weil, 1992). Despite its importance, we still know rather little about how firms, especially SMEs, organize their search for external knowledge aimed at developing process innovations (e.g., Schuster & Brem, 2015; Tsai & Wang, 2009)

2.3. The impacts of external knowledge search on process innovations

Companies can search for new knowledge from a variety of external sources (see, for example, Chiang & Hung, 2010; Laursen & Salter, 2006; Leiponen & Helfat, 2010). Among these, customers, competitors, and suppliers are widely-employed by firms, and have received considerable attention from scholars (e.g., Laursen & Salter, 2006; Zhou & Li, 2012), while universities and academic research have also been shown to be important (Boehm & Hogan, 2013; Lundberg & Andresen, 2012). The various sources differ widely, in terms of the types of knowledge that they offer and how readily the knowledge can be transferred (Sofka & Grimpe, 2010). While it is reasonable to assume that different sources will have different effects on firms' process innovations, few studies have addressed these distinctions empirically (e.g., Un & Asakawa, 2015).

For example, customers represent a valuable external source that companies can use to predict market changes and opportunities in their environment (Tether, 2002). Customers can

also have an active role in bringing new ideas and solutions to firms. On the other hand, Enkel, Perez-Freije, and Gassmann (2005) argue that focusing too much on customers as a source of external knowledge may limit a firm's innovation activities and, ironically, decrease the chances of accurately identifying customers' actual needs. Because customers' ideas depend primarily on their experiences, they tend to provide ideas about products with which they are familiar, rather than offering novel ideas for expanding process innovation (Von Hippel, 2005). External knowledge search from customers may do little help firms to develop process innovations, especially because process innovations are often not obvious to customers (e.g., Terjesen & Patel, 2015; Un & Asakawa, 2015), who thus have limited knowledge about them.

Amara and Landry (2005) and Nieto and Santamaría (2007) highlight the role of competitors in firms' innovation activities. Knowledge may be easier to identify and acquire from competitors, who operate in markets that are similar to those of the focal firm and whose applicable knowledge is largely embedded in tangible products (Dussauge, Garrette, & Mitchell, 2000; Sofka & Grimpe, 2010). However, firms tend to seek to restrict competitors' access to their operational processes. As a result, it may be difficult to gain much knowledge about competitors' processes, especially knowledge with the potential to lead to product development (Un & Asakawa, 2015). While some companies, such as Toyota Motor Corporation, do allow competitors to observe their operational and manufacturing processes, managers at the competitor firms generally find it virtually impossible to observe the detail of how these processes work as systems, severely limiting the utility of the observation with respect to improving process efficiency and product quality in another context (Sobek & Liker, 1998). Therefore, external knowledge search from competitors may not lead readily to process innovation (Un & Asakawa, 2015).

Firms may seek to develop new ideas by searching for knowledge from suppliers (Tsai, 2009). While collaboration with suppliers may help organizations to learn more quickly,

generate new solutions, and accelerate the commercialization of new ideas in the short term (e.g., Dyer & Hatch, 2004), knowledge acquired through collaboration with suppliers may be less valuable for developing process innovation; competitors may also have access to the same knowledge, reducing its value to each individual firm (Köhler et al., 2012). Kotabe (1990) argues that excessive focus on suppliers' knowledge may even prevent firms from effectively developing their own manufacturing processes.

In contrast to these value chain partners, universities and research organizations may be more likely to provide systematic knowledge, some of which may even be tacit (Cohen, Nelson, & Walsh, 2002). Perkmann and Walsh (2007) note that knowledge produced by universities can help firms to develop innovations, due to the often-higher degree of novelty associated with such knowledge. Un and Asakawa (2015, p. 144) assert that "collaboration with a university enables the firm to question how processes are undertaken in the firm and reanalyze the whole process from beginning to end, seeking to achieve higher efficiency and improve product quality". In this way, external knowledge search from universities may provide knowledge that is especially novel, increasing the opportunities for the firm to generate new ideas for commercialization (e.g., Cohen et al., 2002); thus, it offers the potential to help in the development of process innovation.

On the basis of these arguments, we propose the following hypothesis:

Hypothesis 1: External knowledge search from universities and research organizations is more strongly associated with the development of process innovation, compared with external knowledge search from value chain partners (e.g., customers, competitors, and suppliers).

2.4. The mediating role of absorptive capacity between knowledge search and process innovation

While a large body of literature has focused on identifying external sources that have strong impact on firms' product innovation (e.g., Köhler et al., 2012; Laursen & Salter, 2006), few studies have explored the effects of external search on process innovation. For example, Reichstein and Salter (2006) indicate that suppliers have a positive effect, customers have a negative effect, and universities have no effect on firms' process-related innovation activities. In contrast, studying Korean automotive suppliers, Kim, Sohn, Roemer, and Yassine (2006) find that collaborating with universities can assist firms to manage their manufacturing processes and find new ways to better organize their flow of materials. Lukas, Whitwell, and Heide (2013) discuss that knowledge search from customers may not relate to the development of process innovation. In a study of 781 manufacturing firms, Un and Asakawa (2015) find that upstream collaboration, such as that with suppliers and universities, is related to process innovation. Schuster and Brem (2015) note that searching for knowledge from external partners does not have any significant effect on firms' manufacturing capabilities.

One possible explanation for these mixed findings relates to the different contexts in which the studies were undertaken. Scholars have also offered another plausible explanation for these contradictory results, suggesting that external knowledge search may not be sufficient for developing process innovation. According to West and Bogers (2014, p. 821), "identifying and acquiring innovations from external sources is only half the battle"; in order to reap benefits from new knowledge, firms require internal processes and routines that enable them to assimilate, transform, and exploit newly-generated knowledge into their manufacturing processes and facilitate the development of process innovation (e.g., Zahra & George, 2002).

Absorptive capacity (AC) was first defined by Cohen and Levinthal (1990, p.128) as "the firm's ability to recognize the value of new, external information, assimilate and apply it

to reach the organization's goals". Zahra and George (2002, p. 186) emphasize the multidimensional nature of AC and redefine it as a dynamic capability, specifically, "a set of organizational routines and processes by which firms acquire, assimilate, transform, and exploit knowledge". Zahra and George (2002) highlight two aspects of absorptive capacity: "potential" AC, which encompasses a firm's capability to acquire and assimilate external knowledge; and "realized" AC, which focuses on a firm's capability to combine newly-acquired knowledge from external partners with its current knowledge, and exploit it in order to generate new products and processes.

A firm's search based on knowledge from universities, research organizations, and value chain partners can expand its knowledge boundaries; lead it to generate new solutions (Cohen & Levinthal, 1990); and prevent it from focusing too heavily on internal learning ("familiarity traps"), which can limit its investment in unfamiliar technologies (Rosenkopf & Nerkar, 2001; Zahra & George, 2002). In this way, a firm's search from external partners can expand its ability to acquire and assimilate new knowledge (potential absorptive capacity). For example, more extensive relationships with universities, research organizations, and suppliers can increase the chances of accessing different knowledge sources, enhancing the firm's opportunity to develop its potential absorptive capacity (Asakawa, Nakamura, & Sawada, 2010).

Realized absorptive capacity, on the other hand, is associated with activities that facilitate the combination of newly-acquired knowledge with the firm's current knowledge, in order to leverage or create new ideas (Zahra & George, 2002). External search from universities, research organizations, and value chain partners may increase the chance of acquiring valuable knowledge that can be used in conjunction with the knowledge that a firm already has, in order to develop its realized absorptive capacity. As such, having strong relationships with universities, R&D companies, and research organizations can afford firms

access that allows them to update their knowledge, helping them to develop solutions that shorten development cycles and resolve issues more rapidly (e.g., Baum, Calabrese, & Silverman, 2000; Laursen & Salter, 2014).

Therefore, novel ideas created through external knowledge search can help firms to develop their capabilities related to acquiring, assimilating, transforming, and exploiting new knowledge, in order to become process innovators (e.g., Cohen & Levinthal, 1990; Zahra & George, 2002). Hernandez-Espallardo, Molina-Castillo, and Rodriguez-Orejuela (2012) discuss how acquiring and assimilating knowledge from distributors helps manufacturers to expand their capabilities related to developing process innovation, and find that, when collaboration between manufacturers and distributors evolves over time, manufacturers are able to embed newly-acquired knowledge into their operations, and distributors' commitment increases; consequently, the risks associated with generating novel ideas decrease within firms. Soosay, Hyland, and Ferrer (2008) indicate that having relationships with external actors can help a firm to develop its capabilities, which can lead to increased efficiency of operations, higher quality, and lower cost. In line with the above discussion, we hypothesize:

Hypothesis 2a: Potential absorptive capacity mediates the relationship between search from external partners and process innovation.

Hypothesis 2b: Realized absorptive capacity mediates the relationship between search from external partners and process innovation.

In this way, beyond considering the direct relationship between process innovation and both value chain partners and universities/research organizations (Hypothesis 1), we expand our theoretical framework to consider how potential and realized absorptive capacity mediate these relationships. The research model for our study is depicted in Figure 1.

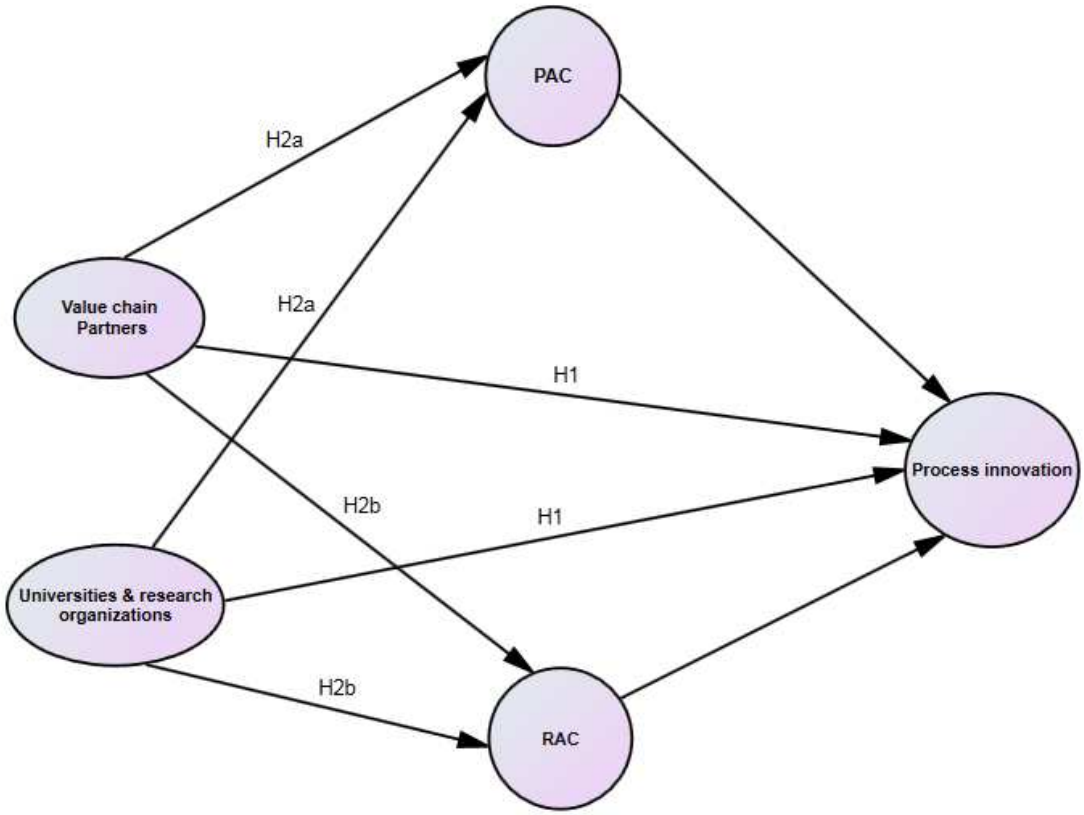


Figure 1: Research Model

3. Research method

3.1. Sample and data collection

We test our hypotheses using survey data obtained from managers of supplier firms in the Iranian automotive industry. We chose this context for multiple reasons. First, this is Iran's largest non-oil industry; with an annual turnover of around 12 billion USD and 12% of the country's workforce, it plays a critical role in shaping the Iranian economy (Business Monitor International, 2015). The industry has had a volatile recent history. Following the imposition of international sanctions, car production in Iran decreased dramatically, from approximately 1,400,000 vehicles in 2010 to about 600,000 vehicles in 2012 (Business Monitor International,

2015). More recently, Iranian suppliers operating in the automotive industry have begun to recover, reaching their 2010 production levels, and some even started exporting products to neighboring countries. This leads to the interesting question of how Iranian firms, facing international sanctions, have developed their manufacturing operations.

Second, operating in an economy facing constraints, Iranian suppliers have strong motivation to tap into outside sources of knowledge to extend their process innovation and, consequently, gain the capabilities necessary to compete in the global market (Ghazinoory, Divsalar, & Soofi, 2009). International sanctions[3] mean that Iranian firms have been largely isolated from international markets, which has limited their operations (Tajeddini & Trueman, 2016). This has created an imperative for them to reduce their expenses substantially, in order to enhance their profitability. Fourth, Iranian policymakers provide strong encouragement for domestic auto manufacturers to continue the development of their designs and manufacturing quality, to produce vehicles based on European and U.S. standards, in order to facilitate exporting; in 2015, President Hassan Rouhani stated that the Iranian automobile industry needs to develop its position to become more competitive in international markets (Elahee, Sadrieh, & Wilman, 2016). Fifth, when Iran joins the World Trade Organization (WTO) in the future, many new competitors will be expected to enter the Iranian market, offering a variety of products. Thus, instead of focusing solely on in-house R&D, Iranian suppliers are now forced to find other sources to assist them in developing their innovations. Therefore, it is crucial for Iranian managers to know how they can benefit more from their external environment, in order to increase their profitability by developing efficiencies and reducing costs (Tajeddini & Trueman, 2016).

[3] Since 1979, the United States has imposed sanctions against Iranian firms. However, theses sanctions were intensified in 2011, due to the Iranian government's uranium enrichment program. This resulted in a substantial drop in domestic car production, and an approximate 300% increase in car prices in 2012. These sanctions were lifted in 2015 (Business Monitor International, 2015), but have recently been reinstated.

The questionnaire used to collect the data for this study was developed using previously-validated measures from the literature, and refined following interviews with 16 senior managers in Iranian automotive supplier companies[4]. The final survey instrument was generated in English, translated into Persian by a professional translator, and then back-translated from Persian to English, consistent with the Douglas and Craig (2007) arguement that an iterative process of translation and back-translation should be carried out until the survey instrument in both versions has similar meanings. The final Persian version of the questionnaire was distributed to potential respondents.

In order to ensure that the items in the survey instrument were fully understandable, we conducted a pilot survey with a panel of R&D, technology, and performance managers, and the head of a material research center. This led to minor changes, such as introducing terms that would be more familiar to Iranian managers. These interviews contributed to our ability to collect valid information. The questionnaire items were measured using seven-point Likert scales.

Based on the interviews, we learned that 250 suppliers play critical roles in the Iranian automotive industry, in terms of having relationships with different external partners. We contacted the managers of these 250 supplier firms by email and telephone, and made appointments with potential respondents in order to ask them to fill in the questionnaire. A total of 200 firms agreed to take part in this study. Finally, we obtained 171 completed questionnaires, representing a 68% usable response rate.

[4] Each interview lasted for approximately 30-60 minutes. These interviews assisted us to develop, refine, and confirm the questionnaire items stemming from the literature.

3.2. Measurement

3.2.1. Dependent variable – process innovation: Process innovation pertains to all activities that lead to the development of productivity and efficiency of production processes (Garcia & Calantone, 2002; Kim, Kumar, & Kumar, 2012). In this study, process innovation was operationalized using a four-item scale (α=0.70), referring to activities that resulted in at least small changes in the methods of producing products or services, aimed at reducing labor costs or cutting the consumption of materials or energy. (e.g., Cohen & Malerba, 2001; Reichstein & Salter, 2006)

3.2.2. Mediator variables – absorptive capacity: In previous studies, AC has generally been operationalized as an unidimensional construct (e.g., Laursen & Salter, 2006) where "either external knowledge is understood, transferred and applied, or it is not" (Bierly, Damanpour, & Santoro, 2009, p. 482). However, the approach of using AC as a single factor, measured as R&D intensity, has been questioned (e.g., Sun & Anderson, 2010). Because AC does not rely solely on R&D intensity, it is important to consider the internal processes that allow a firm to transform and exploit the newly-acquired knowledge in the context of its manufacturing processes and operations (Volberda, Foss, & Lyles, 2010; Zahra & George, 2002).

Therefore, in this study, we follow the Zahra and George (2002) definition of AC, treating this complex concept using a process perspective and operationalizing it as a multidimensional construct, based on existing measures (see, for example, Lane, Koka, & Pathak, 2006; Volberda et al., 2010; Zahra & George, 2002). We operationalized potential absorptive capacity using 12 items (α=0.95) (Jansen, Van Den Bosch, & Volberda, 2005; Szulanski, 1996) and realized absorptive capacity using six items (α=0.91) (Jansen et al., 2005; Smith & Tushman, 2005; Szulanski, 1996; Zahra & George, 2002). The items were each

measured using seven-point Likert scales, with 1 and 7 representing "strongly disagree" and "strongly agree", respectively.

3.2.3. Explanatory variables – Value chain partners and universities/research organizations: Several studies have used patent data and citations to measure knowledge spillovers (Galunic & Rodan, 1997; Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001). However, this approach has some limitations, on the basis that "not all inventions are patentable, not all inventions are patented" (Griliches, 1990, p. 1669). We have taken a different approach in this study, collecting data on firms' external knowledge sources via the survey instrument, asking respondents to assess the importance of the main sources of knowledge for their firms' process-related innovation activities on a seven-point Likert scale, where 1 represents "low importance" and 7 "high importance". Following previous studies (e.g., Köhler et al., 2012; Laursen & Salter, 2006; Sofka & Grimpe, 2010), we used six different sources: competitors, suppliers, customers, universities or other higher education institutes, governmental research organizations, and private research institutes.

We conducted exploratory factor analysis, applying varimax rotation, for the items representing the six types of external sources, and found two factors, each with Cronbach's α values greater than 0.70. From this, consistent with previous studies (e.g., Faems, Van Looy, & Debackere, 2005; Köhler et al., 2012; Rothaermel, 2001; Rothaermel & Deeds, 2004), we divided external knowledge sources into two categories: value chain partners (e.g., customers, suppliers, competitors) and universities/research organizations. Table 1 shows the factor loadings pertaining to external knowledge search.

Table 1: Rotated factor loadings for external knowledge search.

Items	Loadings		Factor name
	1	2	
Competitors	0.34	**0.70**	Value chain partners
Suppliers	0.17	**0.80**	
Customers	0.06	**0.80**	
University or other higher education institutes	**0.89**	0.16	Universities/research organizations
Government research organizations	**0.91**	0.22	
Private research institutes	**0.88**	0.18	

3.2.4. Control variables: In line with previous studies, we controlled for the age of the firm, on the basis that older firms may have more experience and knowledge, which might affect their level of AC. As larger firms are likely to have more available resources, we controlled for firm size, using the number of employees. We also differentiate between privately- and publicly-owned firms, since government-owned companies may have better sources of support. In addition, we controlled for the level of investment in R&D, using the ratio of the number of employees involved in R&D to the total number of employees, with the rationale that this may affect the firm's innovation activities via the development of AC (Cohen & Levinthal, 1990).

3.3. Reliability and validity

Before testing the hypotheses, we employed several approaches to enhance the robustness of the reflective measurement model estimated using PLS (Chin, 1998; Henseler, Ringle, & Sinkovics, 2009). Cronbach's α values and composite reliabilities (CRs) were used to assess the reliability of the constructs. Table 2 provides details regarding the items used in the constructs pertaining to absorptive capacity and innovation, along with the factor loadings, reliabilities, and validity assessments. As shown in Table 2, all of the Cronbach's α values exceed the recommended level of 0.70 (Nunnally, 1967), and the CR values are also above the recommended level of 0.70 (Fornell & Larcker, 1981); therefore, the main constructs pertaining to AC and innovation demonstrate acceptable reliability. Evidence of convergent validity is

provided by the average variance extracted (AVE) values in excess of 0.50 (Fornell & Larcker, 1981), while discriminant validity is demonstrated by the fact that each of the AVEs is greater than the squared correlation between the constructs (Fornell & Larker, 1981).

Table 2: Factor loadings, Cronbach's α, and validity assessment.

	Factor Loading	α
Potential absorptive capacity (CR=0.95, AVE=0.64)		**0.95**
Our company observes external sources of new products and technologies in detail.	0.71	
Our company frequently scans the environment for new technologies.	0.80	
Our company thoroughly observes technological trends.	0.81	
Our company has "information on the state-of-the-art of external technologies within our industry".	0.81	
Our company regularly utilizes new opportunities in the new market.	0.82	
Our company collects industry information (e.g., potential competitors, customer needs, etc.).	0.73	
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".	0.78	
Our company quickly understands new opportunities in our market (e.g., emerging customer needs).	0.77	
Our company quickly analyses and interprets changing market demands (e.g., shifting structure of competition).	0.75	
Our company quickly analyses and interprets new technology trends.	0.78	
"Our employees store technological knowledge for future reference".	0.72	
Realized absorptive capacity (CR=0.93, AVE=0.68)		**0.91**
"New opportunities to serve our customers with existing technologies are quickly understood".	0.82	
Our company regularly matches "new technologies with ideas for new products".	0.80	
Employees "share practical experiences".	0.83	
"We grasp the opportunities for our firm from new external knowledge".	0.71	
Our company regularly applies technologies in new products.	0.80	
Our company considers how to better exploit technologies.	0.74	
Process innovation (CR=0.81, AVE=0.52)		**0.70**
Cut the consumption of materials for products or services.	0.81	
Cut energy consumption for producing products or services.	0.82	
Improve production flexibility for producing products or services.	0.82	
Improve production capacity for producing products or services.	0.77	
Value chain partners (CR=0.83, AVE=0.61)		**0.70**
Competitors	0.70	
Suppliers	0.80	
Customers	0.80	
University and research organizations (CR=0.93, AVE=0.82)		**0.89**

	Factor Loading	α
University	0.89	
Government research organizations	0.91	
Private research organizations	0.88	

Table 3 shows the correlation matrix and descriptive statistics for the variables used in the modeling. As a check for non-response bias, we compared the first 25% and the last 25% of the responses received. The results of *t*-tests comparing the means of a variety of attributes were insignificant, providing some confidence that non-response bias is not a concern for the study. In addition, none of the variance inflation factors (VIFs) calculated for the latent variables in our model exceeds 2.0, demonstrating a lack of problem multicollinearity.

Table 3: Correlations, means, and standard deviations.

	Mean	SD	1	2	3	4	5	6	7	8
1. Process innovation	4.47	1.00	**0.72**							
2. Value chain partners	3.64	1.21	0.28**	**0.78**						
3. Universities & research org.	2.82	1.45	0.25**	0.42**	**0.90**					
4. PAC	4.21	1.23	0.57**	0.24**	0.31**	**0.80**				
5. RAC	3.97	1.32	0.39**	0.32**	0.19*	0.52**	**0.82**			
6. Age of company	21.18	10.57	-0.30**	0.01	-0.04	-0.29**	-0.02	1		
7. R&D intensity	1.79	1.30	0.04	0.22**	0.09	0.10	0.20**	-0.08	1	
8. Employees (2016)	3.30	1.62	-0.03	0.28**	0.07	-0.16*	-0.02	0.30**	0.16*	1
9.Ownership	0.90	0.29	0.01	-0.04	-0.05	-0.04	-0.03	-0.08	0.07	-0.01

Note: Diagonal elements in bold represent the square root of the average variance extracted (AVE).
n=171
$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

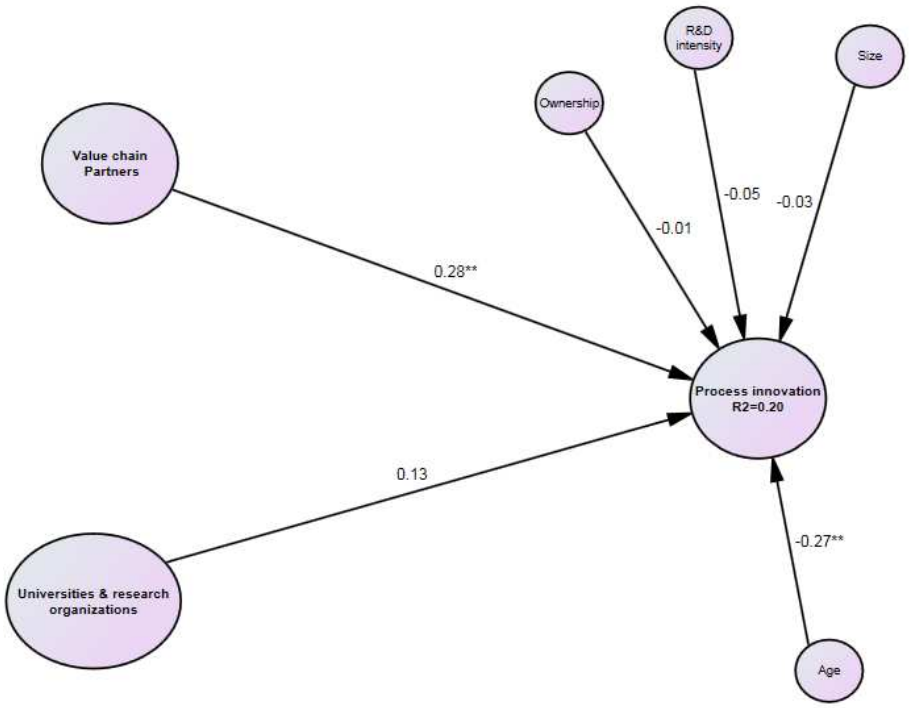
The fact that our dependent and independent variables were based on data collected from individual respondents raises the potential of common method bias; we employed several approaches to minimize its potential impact (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). The items used to measure the dependent and explanatory variables were located in different sections of the survey instrument, and the data collection was completely anonymous in nature. A large pilot study ensured that there was no ambiguity in the items used in the questionnaire, and the 16 in-depth interviews with managers revealed information that was fully consistent with the survey results. In addition, the majority of the suppliers in our study are SMEs (72% with fewer than 200 full-time equivalent employees), and our respondents were nearly all (87%) top managers, suggesting further protection against the effects of common method bias (Gerschewski, Rose, & Lindsay, 2015). Analytically, the result of a Harman's single-factor test revealed that no single factor accounted for more than 26.40% of the variance, also providing evidence that common method bias is not a serious problem for our study (Podsakoff et al., 2003).

4. Analysis

Following the Preacher and Hayes (2004) recommendation for testing for mediation effects, we evaluated the model using the SmartPLS software (Ringle, Wende, & Will, 2005). The strength of the relationships between constructs and the coefficient of determination (R^2) of the endogenous latent variables are two important measures used to evaluate the structural model (Chin, 1998). Based on the recommendation of Chin (2001), we generated standard errors and *t*-statistics using bootstrap estimates based on 500 simulated observations. The estimated path coefficients and their observed significance levels, along with the R^2 values for the endogenous latent variables, are shown in Figures 2-5. The R^2 for each model of the endogenous latent variable exceeded 0.10, suggesting that at least 10% of the construct variability was derived from the research model, following Falk and Miller (1992). Figures 2 and 3 pertain to the full model, while Figures 4 and 5 show separate mediation models for the two sources of external

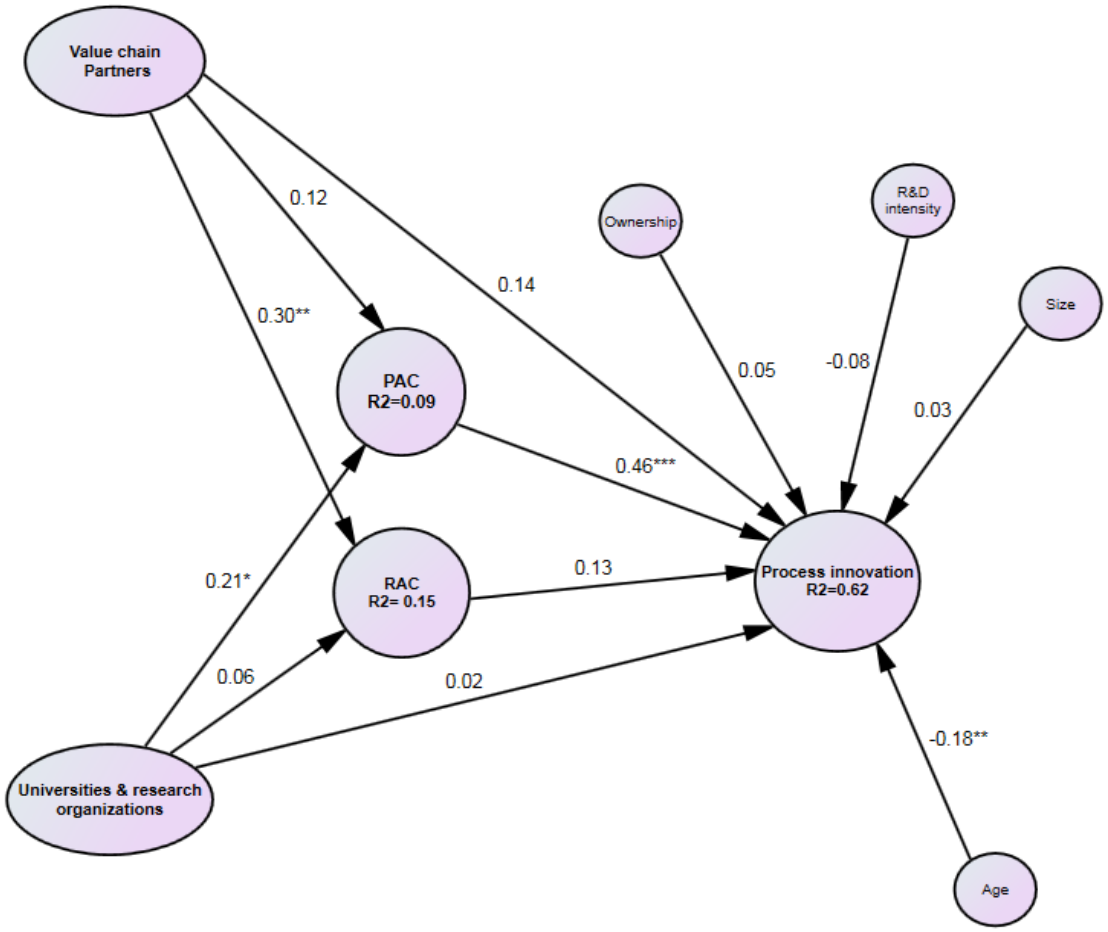
information, the separate models are included to provide additional insight and evidence of robustness.

In Figures 3, 4, and 5, the R^2 values for the models of process innovation that incorporate mediation indicate that the models explain 62%, 42% and 41%, respectively, of the variance; these values each exceed the variance explained of 20% for the direct effect model (Figure 2). While this level of explained variance can be described as "moderate", it is considered to be acceptable when only a few exogenous latent variables explain an endogenous latent variable (Chin, 1998; Henseler et al., 2009, p. 303), thus providing evidence that the mediated models are useful and able to provide insights for understanding process innovation (e.g., Henseler et al., 2009).



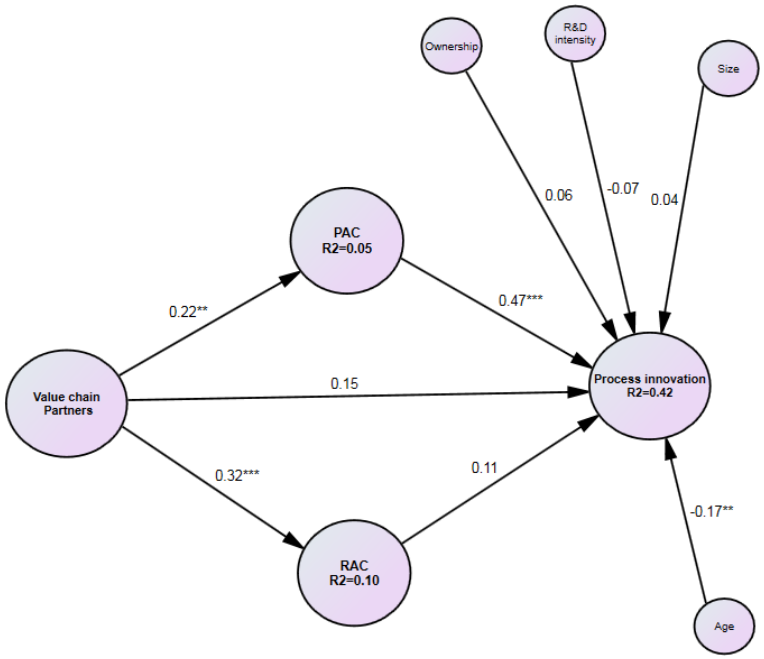
*p<0.05, **p<0.01, ***p<0.001

Figure 2: Direct effect of external sources on process innovation.



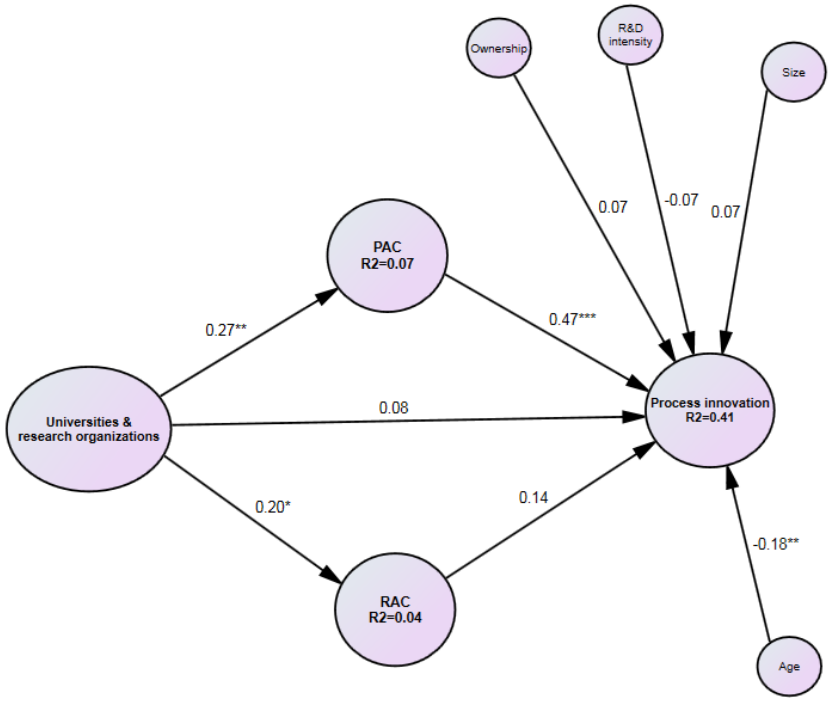
*p<0.05, **p<0.01, ***p<0.001

Figure 3: The mediating effect of AC on the relationship between knowledge search from external sources and process innovation – full model.



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

Figure 4: The mediating effect of AC on the relationship between knowledge search from value chain partners and process innovation.



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

Figure 5: The mediating effect of AC on the relationship between knowledge search from universities and research organizations and process innovation.

Assessing predictive ability is another way to evaluate the structural model. We used the Stone-Geisser Q^2 statistic, a measure of predictive relevance, in this study, computed through a blindfolding procedure (Geisser, 1974; Stone, 1974). When $Q^2 > 0$ for a particular endogenous latent variable, its explanatory variables are viewed as having predictive relevance (Henseler et al., 2009). As shown in Table 4, the value for the Stone-Geisser Q^2 statistic is considerably greater than zero for our dependent variable (process innovation), providing evidence of acceptable predictive accuracy.

Table 4: Inner model evaluation indicators.

Factor	R^2	Q^2
Process innovation	0.42	0.19
PAC	0.08	0.05
RAC	0.11	0.06

4.1. The mediating effect of AC on the relationship between external knowledge search and process innovation

Figure 2 shows the result of estimating the direct model. The estimated effect of knowledge search from value chain partners on process innovation is positive and significant ($p< 0.01$), providing evidence of a direct relationship (Preacher & Hayes, 2004, 2008). In contrast, the estimated effect of knowledge search from universities and research organizations on process innovation is not significant[5]. Combined, these findings contradict hypothesis 1.

The mediated model in Figure 3 provides much stronger explanatory power, relative to the direct model, based on the increased R^2 value associated with process innovation (0.62 versus 0.20). Inference regarding the significance of the indirect (mediation) effects is undertaken using the bootstrap approach discussed earlier, and provides more nuanced insights.

[5] We also conducted a Wald test, which suggested that the difference between the two estimated coefficients is statistically significant ($p<0.01$).

Bootstrapping of the "specific indirect effect"[6] provides observed significance levels; these values are shown in Table 5. The full model thus indicates that only one of the four proposed mediations is significant. Specifically, PAC mediates the relationship between external knowledge search from university and research organizations and process innovation (p<0.05) for the firms in our sample. On the other hand, RAC does not mediate the relationship between knowledge search from either type of external source and process innovation. Therefore, hypothesis 2a receives partial support (for universities and research organizations, but not for value chain partners), and hypothesis 2b is not supported.

Table 5: Specific indirect effects of external search on process innovation **(full model)**

Path	**Specific indirect effect**
Value chain partners ⟶ PAC ⟶ Process innovation	0.05
Value chain partners ⟶ RAC ⟶ Process innovation	0.04
Universities & research organizations ⟶ PAC ⟶ Process innovation	0.10**
Universities & research organizations ⟶ RAC ⟶ Process innovation	0.01

$^{*}p$<0.05, $^{**}p$<0.01, $^{***}p$<0.001

In order to further assess the mediation effect, we analyzed the strength of the impacts of PAC and RAC by considering effect sizes based on the Cohen (1988) f^2 value, for which 0.02, 0.15, and 0.35 indicate small, medium, and large effects, respectively. As shown in Table 6, the only mediation of interest is that of potential absorptive capacity on process innovation, based on its medium-level (f^2 = 0.20) effect size.

[6] In the multiple mediation model, the specific indirect effect (calculated in Smart PLS 3) represents the indirect effect of value chain partners on process innovation through PAC (Hair, Hult, Ringle, & Sarstedt, 2016). For example, in Figure 3, the specific indirect effect for universities and research organizations through PAC is calculated by multiplying the associated path coefficients (0.21*0.46=0.10).

Table 6 Effect sizes

Effect	R^2 included	R^2 not included	f^2
Value chain partners → Process innovation	0.42	0.41	0.01
Universities & research organizations → Process innovation	0.42	0.42	0.00
PAC → Process innovation	0.42	0.30	0.20
RAC→ Process innovation	0.42	0.42	0.00

Given that there is some correlation between our two key explanatory variables pertaining to external sources, we also investigate their relationships with process innovation individually, in order to gain additional insights. These results are shown in Figures 4 and 5.

4.2. The mediating effect of AC on the relationship between knowledge search from value chain partners and process innovation

In the mediated model shown in Figure 4, the results indicate that, when knowledge search from universities and research organizations is not included, the specific indirect effect of value chain partners on process innovation, mediated by PAC (0.22*0.47=0.10), is significantly different from zero (p<0.01). Following Kenny (2016), nearly 40%[7] of the relationship between knowledge search from value chain partners and process innovation is mediated by PAC.

Consistent with the full model, we find no evidence that RAC mediates the relationship between knowledge search from value chain partners and process innovation (Hayes, 2009); the specific indirect effect of value chain partners on process innovation through RAC (0.32*0.11=0.03) is not significantly different from zero. The fact that the estimated effect of

[7] The indirect effect divided by the total (indirect + direct) effect (0.10/(0.10+0.15) = 0.40) indicates the proportion of the effect that is mediated (Kenny, 2016).

RAC on process innovation is not significant (p>0.10) provides additional evidence of RAC's lack of mediation of the relationship.

4.3. The mediating effect of AC in the relationship between knowledge search from universities, research organizations and process innovation

Estimating the model shown in Figure 5 reveals that, when the relationship between universities and research organizations and process innovation is mediated by PAC and RAC, the specific indirect effect of knowledge search from universities and research organizations on process innovation through PAC (0.27*0.47=0.13) is significant (p<0.01). Thus, consistent with the full model, PAC mediates the relationship between knowledge search from universities and research organizations and process innovation (Hayes, 2009); 61% of the relationship is mediated by PAC in this reduced model. Also consistent is the finding that RAC does not serve as a mediator of the relationship, based on the insignificance (p>0.10) of the specific indirect effect.

4.4. *Post-hoc* analyses

To further evaluate the robustness of our results, we also examined the relationships between process innovation and each of the six individual external sources considered in the study, as shown in Table 1. This *post-hoc* analysis reveals that only knowledge search from competitors displays a positive and significant (p< 0.01) relationship with process innovation. This may be due to the fact that Iranian firms in the automotive sector have been under governmental pressure to produce high-quality products at low prices, and the international sanctions have impeded the firms' access to global knowledge that can help to improve their manufacturing processes. Since competing firms possess relevant capabilities and confront similar obstacles, relationships with them may enable firms to acquire and transform technologies that assist in the development of process innovations (see, for example, Gnyawali & Park, 2011; Ritala,

Hurmelinna-Laukkanen, & Blomqvist, 2009). Such collaborations can assist firms to gain access to knowledge and capabilities that they may not otherwise be able to obtain, and contextual similarity may facilitate the process of integration for developing process innovation (Sampson, 2007). Previous studies have noted that collaborative relations tend to be between firms within same industry, and especially among competitors (see, for example, Gnyawali & Park, 2011; Harbison and Pekar, 1998). Drivers of this counter-intuitive result may include ever-shorter product life cycles, the need to invest heavily in R&D, the increasing importance of technological standards, and technological convergence (Garud, 1994; Gnyawali and Park, 2009; Gomes-Casseres, 1994).

5. Conclusion and implications

Manufacturing firms work under pressures related to both cost and innovation, consistent with shortened product life cycles and accelerated development processes (Brem et al., 2016; Dilk, Gleich, Wald, & Motwani, 2008; Ili, Albers, & Miller, 2010; Utterback & Abernathy, 1975), and the emergence of dominant design creates the need to develop operational efficiencies in a systematic manner (Oltra & Saint Jean, 2009; Schroeder, Linderman, Liedtke, & Choo, 2008). While many of these pressures pertain to processes, there is still a rather limited understanding of the impact of knowledge search on firms' process-related innovation activities (Crossan & Apaydin, 2010; Piening & Salge, 2015). Despite clear theoretical and practical implications related to the development of manufacturing processes and process technologies (Robertson, Casali, & Jacobson, 2012), previous studies in the open innovation literature have focused primarily on product innovation (Piening & Salge, 2015; Tsinopoulos et al., 2017). This creates a need to understand more about the linkage between firm openness and the development of process innovation (Schuster & Brem, 2015).

Our study contributes to the open innovation literature by examining how firms' search strategies are related to the development of process innovation in an emerging economy. In

contrast to our expectations, we find that only PAC – and not RAC – mediates the relationship between knowledge search from external partners and process innovation, and that search based on knowledge from the firm's value chain partners is more important for the development of process innovations than knowledge search from universities and/or research organizations. An explanation for the relative importance of value chain partners may be that auto suppliers, who tend to be rather small and operate on the second tier in the hierarchy of the industry, are likely to have relatively few opportunities to interact with universities and research organizations. Their more extensive experience with value chain partners – especially competitors – may facilitate the development of process innovation through greater shared understanding of the mechanisms by which firms identify, understand, and translate externally-generated knowledge into their operational systems.

Zahra and George (2002) discuss the notion that past experience has an impact on the development of PAC, through path-dependent search abilities, which affect external AC routines; see Lewin, Massini, and Peeters (2011). Such external AC routines can be aimed at "identifying and recognizing the value of externally generated knowledge, learning from and with external sources or transferring knowledge back to the organization" (Lewin et al., 2011, p. 90), and can expand, refine, and adjust as an outcome of previous experience. In other words, what firms have done in the past distinguishes the type and the diversity of PAC routines that they are capable of developing, and the impact that the routines have on process innovation (Lewin et al., 2011). Since the nature of process innovation is especially tacit and complex, firms need to overcome more barriers relating to assimilation and interpretation, relative to product innovation. Past experience assists firms to expand and refine the external AC routines that will eventually influence their capabilities to understand externally-generated knowledge and act upon it. Accordingly, Zahra and George (2002, p. 193) note that "a firm's potential absorptive capacity is a path-dependent capability that is influenced by its past experiences that

are internalized as organizational memory". Our findings are thus in keeping with the critical role of organizational memory for firms aiming to develop their process-related innovation activities.

Furthermore, past experience can help firms via two mechanisms. Firstly, over time, firms learn how to manage their ongoing relationships with external partners more efficiently, developing organizational routines and mechanisms. Secondly, managers become more expert at identifying and selecting external partners, based on their experience from previous linkages (Love, Roper, & Vahter, 2014). Our results are consistent with the idea that collaboration-based learning can help firms to become more expert in managing their external partners, through the development of higher-level organizational routines, which then form the basis for their future collaborations. These findings respond to a question raised by Love et al. (2014, p. 1715), pertaining to open innovation: "Do the learning effects occur mainly through better selection of collaborative partners or through improved management of external relationships?" We find evidence suggesting that the learning effects of external scanning are stronger when a firm knows how to manage external searches more effectively, in terms of its external absorptive capacity routines.

On the other hand, RAC does not mediate the relationship between external scanning and process innovation. It may be that, while searching for knowledge from external sources can enable firms to access novel solutions that have previously been unexplored within the organization (Amabile, 1988), a substantial gap exists between the newly-acquired knowledge and the firm's current stock of knowledge. Firms with insufficient RAC are likely to face difficulties in transforming and exploiting novel ideas during search processes (Bell & Pavitt, 1997), impeding the ability to use the external knowledge to introduce new process-related innovations. This is especially salient in more mature industries, where the knowledge gap may mean that more time is required to develop process-related innovations from external

knowledge searching. A danger apparent in such a situation is that, if technological knowledge changes quickly, the result of the transformation and exploitation of newly-acquired knowledge may be out of date by the time process innovation can be achieved (Tsai, 2009). In this way, the process of searching for knowledge from the external environment in the context of a mature industry can become even more uncertain and costly. This scenario may exacerbated in our study; as most of the firms are SMEs, they may have fewer resources and capabilities for digesting advanced technologies, relative to larger firms.

In this paper, we contribute to the literature through a reconceptualization of absorptive capacity, considering it more theoretically, from a process perspective. We provide empirical evidence that a firm's capability for acquiring and assimilating external knowledge (i.e., potential absorptive capacity) plays a key role in the development of process innovation. Specifically, we find evidence that new knowledge gained from external sources loses its value if the firm does not have potential absorptive capacity in place.

Finally, most of the empirical studies on open innovation have focused on large multinational enterprises (Chesbrough, 2003; Laursen & Salter, 2006) in high-technology industries, such as software (Henkel, 2006). Previous scholars have explained how these large companies acquire knowledge from different external sources in order to develop innovation (e.g., Dodgson, Gann, & Salter, 2006). To date, there have been relatively few open innovation studies that focus on SMEs operating in an emerging country (exceptions include Brunswicker & Vanhaverbeke, 2011; Lee, Park, Yoon, & Park, 2010). Our study also responds to a call for more research on studying open innovation in the context of the automotive industry, which has seldom been a focus in this literature (for exceptions, see, for example, Lazzarotti et al., 2013; Schuster & Brem, 2015). Table 7 summarizes the key results derived from our study, and their implications.

Table 7
Summary of key findings and implications

Key results	Implications
External knowledge search from value chain partners is related to the development of process innovation.	PAC mediates the relationship between external scanning and process innovation (when search from universities and research organizations is not included in the model). Past experience plays a key role in expanding and refining external absorptive capacity routines, helping firms to manage their relationships with external partners more efficiently, and assisting managers to become experts at identifying and selecting suitable collaborative partners (e.g., Love et al., 2014). Organizational memory plays a critical role for firms aiming to develop their process-related innovation activities.
External knowledge search from universities and/or research organizations is not directly related to the development of process innovation.	RAC does not mediate the relationship between knowledge search from universities and research organizations and process innovation, but PAC does. Firms with underdeveloped RAC may confront difficulties in combining and exploiting new solutions during search processes. The learning effects of external linkages may occur mainly through better management of external linkages. SMEs' more limited resources and capabilities, compared to larger firms, may make it more difficult for them to digest more theoretical or highly-technical knowledge, such as that available from universities and research organizations.

6. Practical implications

Our results provide some insights for managerial practice. First, our findings emphasize that it is important for managers operating in an emerging economy to draw knowledge from external sources in order to develop process innovation. Second, our study provides evidence that acquiring and understanding external knowledge is necessary, but not sufficient, for developing process-related innovation activities. Firms also need to have internal capabilities that allow them to transform and exploit newly-acquired knowledge, embedding it into their operations in order to fully benefit from the knowledge search. Thus, managers should not only monitor their firms' external environments, but also expand their firms' own mechanisms and routines, in order to put the externally-generated knowledge into practice (Zahra & George, 2002). Third, since innovation and its outcomes are inherently uncertain, it is important for managers – especially those in a mature sector – to select collaborative partners based on the kind of knowledge and innovation that their firms require. We find evidence that, in order to develop process innovations, the Iranian managers in our study search for knowledge pertaining to process innovation more from value chain partners than from universities and research organizations, purposively searching for key external sources. This does not imply that searching for knowledge from universities and research organizations is a poor strategy; rather, it highlights the risks and difficulties associated with searching for novel ideas in pursuit of the introduction of process innovations. Managers need to be very careful about such searches, and bear in mind that not all external knowledge sources are equally useful or usable. The fact that competitors appear to be the most potent sources of external knowledge for the firms in our sample makes clear the importance of managers' being open to potential collaborations within their own industry, in order to access and transfer new technologies that allow them to develop their capabilities and improve their innovation-related outcomes.

In addition, our findings suggest that external search may not only affect current innovation activities, but that it may also help firms to benefit further from future collaborations with external sources, if they are able to build on their current experience. Our results support the concept of learning effects that take place over time (see, for example, Love et al., 2014). On this basis, managers may be advised to pay attention to retaining experience related to collaborating with external partners within the firm for future reference. Finally, as most of the firms in our study are SMEs, we have shown how drawing knowledge from external sources is important for smaller firms operating in a traditional sector.

6.1. Limitations and directions for further research

Our work is subject to some limitations, which may open up future lines of research. While deep coverage of the Iranian automotive context is a strength of the study, we acknowledge that this research was conducted in a specific context that may limit its generalizability. It would be interesting to address the impacts of AC on process innovation in other geographical contexts (including advanced, emerging, and developing economies) and a range of industries in both the manufacturing and service sectors. While we are looking at process innovation and external knowledge search in Iran, a country that has been under economic sanctions for many years, our findings can also apply to other countries subject to political isolation, such as Cuba, Belarus, Libya, Sudan, Egypt, Iraq, and Russia. Firms operating in these countries have also suffered from varying degrees of international sanctions in recent years, and some face prospects of increased restrictions on their cross-border interactions. As free trade comes under increasing threat globally, more firms are likely to face constraints (albeit not as extreme) in their search for knowledge from international partners.

A second limitation pertains to our focus on inbound open innovation; future studies may explore how outbound open innovation helps firms to develop and introduce new process innovations. In addition, it would be a fruitful area for further work to investigate how the

various external sources (e.g., competitors, suppliers, universities, customers) are related to the development of potential and realized absorptive capacity and how these two dimensions of absorptive capacity then foster the generation of competitive advantage. It would be also interesting to investigate more about the conditions under which collaboration with competitors evolves and how absorptive capacity affects such co-opetition.

Another limitation pertains to the potential for common method variance (CMV). While a full collinearity assessment approach suggested that our findings are not adversely affected by CMV, we cannot ignore the potential of CMV-created bias in our work. The nature of CMV's impact on models is difficult to predict, and it is conceivable that, for example, a firm's existing capabilities with respect to process innovation may affect the manner in which a respondent perceives the firm's potential for learning from partners to assist in developing further process-related improvements.

In future work, the use of a longitudinal approach may shed further light on the dynamic nature of AC and its role in the development of innovation-related success. It would be also interesting to explore the potential negative impact of firm openness on the development of process innovation. Future research in the open innovation literature may also focus more on the critical role of organizational memory in shaping the locus of a firm's external knowledge search (Rosenkopf & Nerkar, 2001; Zahra & George, 2002), and its impact on the development of process innovation. In addition, while we have focused on process-related innovation activities, it may be useful to investigate other types of innovation, such as management innovation and service-related innovation activities, especially in a mature sector. Finally, it might be interesting for future studies to address how other factors, such as company structure and culture, affect PAC, RAC, and process innovations.

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