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Playing 3D chess, or how firms can thrive under complexity: The mediating role of innovation capabilities in the use of innovation input☆

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ABSTRACT

Firms differ not only in their investments in input for innovation but also in their innovation capabilities, i.e., their ability to transform innovation input into innovation output and commercial gain. This paper brings together the process- and management-oriented factors that determine innovation outcomes. Specifically, we attempt to incorporate innovation capabilities into the innovation process and analyze their role in converting innovation input into innovation output and, ultimately, value creation. We also hypothesize about the influence of contingencies on these relationships, most notably the role of procedural and contextual complexity. By using a cross-national data set of over 4500 firms along with dynamic capabilities theory, we find that innovation capabilities enhance the innovation process by improving firms' transformation of innovation input into innovation output. We also find support for our hypothesized role of complexity.

1. Introduction

Innovation is often the result of complex processes that simultaneously involve a multitude of parameters (Dias, Pedrozo, & da Silva, 2014) (i.e., *procedural complexity*, Vasconcelos & Ramirez, 2011). Moreover, innovation often takes place in response to complex and dynamic markets and business environments (i.e., *contextual complexity* (ibid.)). Nevertheless, these complexities are still not widely recognized in innovation management research (Dias et al., 2014; Keupp, Palmié, & Gassmann, 2012; Tidd, 2001). Much of the literature on innovation processes focuses on the role played by innovation input (most commonly R&D) in generating output. Specifically, most studies appear not to recognize the complexities of the processes, the influence of the external environment, or the role that management can play in remedying them (Keupp et al., 2012). Moreover, for their part, strategic management scholars seem to agree that there exists a positive relationship between input and output in the innovation process but that "the 'slope' of this relationship likely differs among organizations because of the complexity of innovation management" (Duran, Kammerlander, van Essen, & Zellweger, 2015, p. 1227). In other words, firms are heterogeneous not only in their level of innovation input (e.g., R&D) but also in their conversion of said input into output, as well as their ability to handle the inherent complexities of innovation.

There is a great need to better understand these heterogeneities and how they relate to each other, conceptually as well as empirically. Indeed, a considerable amount of the literature is concerned with innovation as a process, understanding its variation and its efficacy (Baregheh, Rowley, & Sambrook, 2009; Meissner & Kotsemir, 2016; Rothwell, 1994; Saunila, 2019). This literature, however, has tended to overlook the roles that strategic management and innovation capabilities may play in shaping the process of changing input into output (Crossan & Apaydin, 2010; Gloet & Samson, 2016; Mir, Casadesús, & Petnji, 2016). On the other hand, an equally broad segment of the literature addresses the capabilities of firms working to deliver innovation (i.e., their innovation capabilities) (Breznik & Hisrich, 2014; Lawson & Samson, 2001; Wang & Dass, 2017). Through their management decisions, firms invest in innovation capabilities designed to enhance innovation outcomes (Lawson & Samson, 2001). Typically, these innovation capabilities enable firms to look outward for new opportunities (i.e., sensing, Teece, 2007 or to perform open search, Laursen & Salter, 2006), but these capabilities can also be internal in scope (e.g., seizing, Teece, 2007, developing personal skills and

☆ In a memorable moment from the TV sitcom "The Big Bang Theory," two of the main characters, Leonard and Sheldon, play a game of 3D chess. The genius Sheldon is mundane and simplistic when he plays regular chess but thrives when an extra dimension is added to the game. On the other side of the board, Leonard cannot cope with the complexity of the 3D chessboard. Inevitably, Sheldon wins easily and sardonically notes that "it must be hard to suck on so many levels." Sheldon thrives under complexity, and the situation offers a certain, albeit simplistic, analogy to business processes of various complexity and the actors operating in them. Admittedly, the analogy is imperfect, but innovation is often the result of complex processes that simultaneously involve a multitude of parameters.

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expertise, McKelvie & Davidsson, 2009, learning systematically, Zollo & Winter, 2002, and experimentation, Eisenhardt & Martin, 2000). These *management-oriented* contributions are found mainly in the strategy and innovation management literature. What is not entirely clear in this literature, however, is the extent to which and the manner in which innovation capability affects innovation. One reason is that the literature has focused on understanding the characteristics of innovative organizations and how managers can enhance their firms' innovation (Mir et al., 2016; Saunila, 2019; Wang & Dass, 2017). As Kahn (2018) has recently reminded scholars, however, "innovation is not the same thing as innovative or innovativeness" (p. 459). He elaborates on this by stating that "a common misunderstanding is the tendency by some individuals and organizations to casually use the terms innovative and innovativeness as synonyms of innovation. They are not. Innovative is an adjective whereas innovation is a noun" (Kahn, 2018, p. 454). Reflecting on this, Kahn argues that there is a clear need to distinguish between innovation and innovative/innovativeness in the literature. Building further on this, we argue that there is a need to better delineate innovation and innovative/innovativeness, with the latter being defined as "the capability and capacity for innovation" (ibid., p. 454). Moreover, the influence of an organization's capacity for innovation (its innovation capability) on innovation as a process and innovation as an outcome (Crossan & Apaydin, 2010; Kahn, 2018; Saunila, 2019) needs to be better understood. Therefore, the purpose of this paper is to examine whether and how an organization's capacity for innovation (innovation capability) influences innovation outcomes. We address this important gap in our understanding of innovation by integrating innovation capabilities into the innovation process and analyzing their role in converting innovation input into innovation output and, ultimately, value creation. Moreover, the environmental context matters for innovation (Laursen & Salter, 2006; Zahra, 1996), the product development process (Revilla, Prieto, & Prado, 2010), and how opportunities are captured (Hsieh, Nickerson, & Zenger, 2007). Thus, the role of innovation capability may be particularly salient in the presence of complexity, such as highly uncertain innovation processes in which firm management may direct existing assets and resources and guide how they may be reconfigured to manage complexity. Consequently, complexity may be crucial in understanding the boundary conditions of the innovation capability approach in particular and the innovation process in general. Such contingencies are important elements for a fuller understanding of the theory and theory development in general (Makadok, Burton, & Barney, 2018) and the role of innovation capabilities in the innovation process in particular. By combining input–output-value creation with a more comprehensive understanding of innovation capabilities, as well as the contingent role of complexity, we answer the call, as made by, for example, Keupp et al. (2012), for a more integrated approach "since many questions pertaining to the strategic management of innovation are still little understood" (ibid., p. 368). The research question is as follows:

To what extent does innovation capability influence the relationship between (a) innovation input and innovation output and between (b) innovation output and commercialization, and how is this process contingent on the external and internal complexity of the firm?

This is important to our understanding of how innovation is generated, as innovation is increasingly seen as the path to a firm's long-term competitive advantage. As we know that firm resources and capabilities contribute to heterogeneity in firm performance (Barney, 1991; Schilke, Hu, & Helfat, 2018), insight into the interplay between firm resources and capabilities, and the way in which a firm's innovation takes place, seems crucial. Moreover, in the face of growing complexity, our analysis offers additional insight into the contingent relationship between the efficacy of strategic management and complexity.

This paper makes three contributions to the extant literature. The first contribution is theoretical. We theorize about the role of innovation capabilities in the innovation process and how different types of capabilities work in tandem to enhance the innovation outcome of a firm. When combined with empirical analysis, this theoretical analysis will help us better understand how innovators can take better advantage of innovation (Cohen & Levinthal, 1990; Collis & Montgomery, 1998; Prahalad & Hamel, 1990; Teece, 1986). Scholars have long been puzzled by the question of why innovators are not always the ones who profit from their own innovations. Although this literature has implicitly highlighted the role of innovation capability, there is a great need to make such relationships explicit in theorizing about innovation, as reflected in Kahn's critique discussed above (Kahn, 2018). Progress along such a path is key to understanding innovation, how firm management can influence innovation, and the boundary conditions of the relationship between innovation as a capability and innovation as an outcome. Second, as a contingency contribution, we theorize about the role of complexity and argue that innovation capabilities work better under conditions of high complexity. Finally, we use an empirical technique uncommon in management research (i.e., item response theory) (Carroll, Primo, & Richter, 2016) to capture the dimensions of the concepts involved in the theory. This is a methodological contribution in its own right.

The rest of the paper is organized as follows. First, we present some working definitions of our main constructs before theorizing about their relationships. We then go on to test our hypothesis using item response theory and linear and logistic regression, as well as a mediation analysis under various conditions. We discuss the results and propose future directions for research.

2. Innovation processes and innovation capabilities

Idiosyncrasies in firm innovation seem to stem largely from two factors. First, the ability to invest in R&D, patents, licensing, software, staff training, and design capabilities matters. These may be regarded as crucial inputs to innovation as a process (Duran et al., 2015) and represent a firm's core assets and resources that may be used to create innovative solutions in myriad ways. The second source of heterogeneity stems from how a firm manages innovation as a process, including the input factors, as well as the extent to which a firm's management actively nourishes the capacity of the organization for innovation, including an organization's members (Kahn, 2018). In this section, we will also explicate the role of each of these factors: Innovation resources and *innovation capabilities*.

2.1. Definitions

The innovation process has been thoroughly debated in the literature (Adams, Bessant, & Phelps, 2006), which has presented a variety of perspectives (Eveleens, 2010). The overall development of the innovation process research has been a movement from firm-level analysis to horizontally and vertically integrated models. Rothwell (1994) and Kline and Rosenberg (1986) present synopses of the development of innovation from processes at the firm level of "market pull" and "technological push", through a "coupling model" with interactions among firm functions, to a "chain-linked" model with supplier integration. The shift outside the firm organization itself has continued into the systems integration of the "networking model" (Meissner & Kotsemir, 2016) and later the seminal paradigm of "open innovation" (Chesbrough, 2003). This evolution implies that external relationships are becoming increasingly important for the innovation process. Specifically, innovation processes within a firm must adapt to their surroundings and shifting conditions, enhancing the importance of adapting existing resources to changes. Consequently, the relationship between the strategic management and the innovation process has increasingly become a focal point for research (Keupp et al., 2012), as "decades of research on the management of technology and innovation (...) failed to provide a comprehensive framework to guide innovation research or management practice" (Tidd, 2001, p. 173).

In tying these two streams of research together, we suggest a simple input–output model of innovation in which input is transformed into output, which in turn generates some gain from innovation through commercialization.

By *innovation input* we mean the resources and routines put into the efforts to create innovation, whose composition has been widely addressed in the literature (see Becheikh, Landry, & Amara, 2006 for a review). *Innovation output* means new products, processes, business models, and organizational traits that are the results of a purposeful enactment of resources (van de Ven & Poole, 1995). *Innovation gain and commercialization* refer to business model development and the conversion of innovation into actual value added.

Innovation capability (IC) is the main independent variable of our analysis and is defined as "the ability to continuously transform knowledge and ideas into new products, processes and systems for the benefit of the firm and its stakeholders" (Lawson & Samson, 2001, p. 384).

Although its comprehensive and widely accepted definition remains elusive (Jacobs, 2013), we accept a working definition of *complexity* as "a state manifested by the multiplicity, diversity and functional interrelatedness of elements" (Jacobs & Swink, 2011, p. 677). Complexity has many sources and facets, but for the purpose of studying the innovation process and the role of innovation capabilities, two separate types of complexity are relevant. Vasconcelos and Ramirez (2011) distinguishes between *procedural complexity*, which concerns "the difficulty to solve a given, well-defined problem" (ibid., p. 237), and *contextual complexity*. The former entails the resources invested in a process (e.g., the innovation process) and the variety of these resources. In innovation, this would amount to the resources put into generating a certain innovative output, i.e., the input of the innovation process itself. In this regard, diversity (Jacobs, 2013) becomes a driver of procedural complexity. Contextual complexity, on the other hand, relates to "situations in which finality is not *a priori* known, or knowable, by the actor in question" (Vasconcelos & Ramirez, 2011, p. 237). Moreover, it relates to ambiguous and dynamic environments in which information is not easy to acquire and the environment is volatile, with high variability (Jacobs, 2013).

2.2. Innovation process

The accessibility of resources as input into the innovation process is crucial. Increased access to resources leads to higher levels of innovation output. At its most fundamental level, innovation research is concerned with a simple input–output model (Adams et al., 2006) in which innovation output is seen as a function of the efforts put into the innovation process. As for the relationship between innovation input and innovation output, there seems to be a consensus that it is a strong, positive one. Consequently, we propose a simple and well-established hypothesis about this relationship:

H1. Innovation input has a positive relationship with innovation output.

The input–output model can be easily extended to include the commercialization of innovation of in-demand products or services or cost savings due to improved organizational routines and processes (Adams et al., 2006; Meissner & Kotsemir, 2016). This extension has been tested and demonstrated through several empirical contributions (Rajapathirana & Hui, 2017). Firms differ not only in their ability to generate innovation output from innovation input but also in their conversion of the output of the innovation process into commercial offerings or cost reductions with performance gains. A firm with strong outcomes from the innovation process would not necessarily be able to transform these into commercial gains, but a link between innovation output and commercialization seems rather trivial. As innovation output itself is a function of innovation input, and some input resources are themselves relevant to the process of commercialization, we expect a positive direct relationship between innovation input and commercialization. Thus, we propose the following hypothesis:

H2. Innovation input has a positive relationship with a firm's ability to commercialize.

2.3. Innovation capabilities

Duran et al. (2015) argue that "while most researchers assume that a positive correlation exists between innovation input and innovation output, the 'slope' of this relationship likely differs among organizations because of the complexity of innovation management" (ibid., p. 1212). This suggests that firms vary with respect to their ability to use input and transform it into innovation output. This conversion of input into output has been empirically suggested (Lin, Lee, & Hung, 2006) and studied from different perspectives and conceptualizations, such as the productivity of R&D (Gwynne, 2015) and the innovation conversion rate (Duran et al., 2015). In this paper, we study this issue through the lens of innovation capability as a theoretical perspective. Thus, we go deeper into the issue of how firm management can influence the relationship between input and outcomes in the innovation process, as called for in recent reviews (Crossan & Apaydin, 2010; Kahn, 2018; Saunila, 2019).

Considering the above discussion, we would expect a higher level of innovation capability to yield a better innovation outcome and an improved ability to commercialize from innovation, but the strength of this relationship, and how innovation capability influences innovation in firms, is open for debate. One position in this debate might be that firm management and innovation capabilities do not really matter (Geroski, Machin, & Van Reenen, 1993; Hannan & Freeman, 1984; Therrien, Doloreux, & Chamberlin, 2011). To make such an argument, however, would be to ignore a rich literature on strategic management arguing that organizational capability is an important source of competitive advantage, with innovation being a clear way for firms to reap improved performance (Barney, 1991; Collis & Montgomery, 1998; Nelson & Winter, 1982; Prahalad & Hamel, 1990). On the other hand, it seems optimistic to assume that firm management and innovation capability largely "trump" the role of innovation input in achieving innovation output. Such a position in the debate would ignore decades of research showing that innovation input, such as R&D, is crucial for the development of new products, services, and processes (Cohen & Levinthal, 1989; Mir et al., 2016; Saunila, 2019). Instead, a middle-ground position, as adopted in the present paper, is that innovation capability somehow influences the relationship between input and outcomes in the innovation process. In this regard, and building further on the extant research and the arguments above (Wu, 2007), we suggest that innovation capabilities will partially mediate the relationship between innovation input and innovation output in the innovation process.

H3a. Innovation capabilities partially mediate the relationship between input and output.

H3b. Innovation capabilities partially mediate the relationship between output and commercialization.

The antecedents of dynamic capabilities originate from a firm's internal resource base and external inter-organizational relationships (Ambrosini & Bowman, 2009; Eriksson, 2014). In other words, certain capabilities are related to processes within a firm, such as teamwork, multidisciplinarity, openness to new ideas, and internal communication. We call these *internal capabilities*. On the other hand, *external capabilities* refer to cooperation, alliances, and relationships with actors and processes outside the firm. The internal/external distinction is related to the focus of the capabilities, not to their sensing, seizing, or transforming abilities.

Internal human capital and technological knowledge are demonstrably related to innovation outcomes. Specifically, studies of new product development offer valuable insight into this subject (e.g., Evanschitzky,

Eisend, Calantone, & Jiang, 2012). Internal capabilities as such will act to enhance other resources put into the innovation process. At the individual level, this entails personal skills and expertise in creating novel solutions from existing or new resources (McKelvie & Davidsson, 2009). At the organizational level, this covers an organization's ability to learn systematically (Cepeda & Vera, 2007; Zollo & Winter, 2002) and transform experience into new knowledge creation. Other mechanisms at play with internal capabilities include entrepreneurial leadership (Augier & Teece, 2009), experimentation and learning (Eisenhardt & Martin, 2000), cross-organizational teams designed to coordinate and integrate resources (Ambrosini & Bowman, 2009), and the reconfiguration of organizational structures through the acquisition of business units (Karim, 2006).

Internal capabilities alone, however, might be insufficient as sources of renewal (Chesbrough, 2003). Capabilities also have an external orientation and manifestation (Clausen & Madsen, 2011; Laursen & Salter, 2006). These capabilities to leverage networks, customers, suppliers, and other relationships and resources exogenous to the firm (Houghton, Smith, & Hood, 2009) are our notion of external capabilities, and they are arguably of increasing importance (Jung et al., 2018). Other central mechanisms discussed in the literature include environmental scanning (Danneels, 2008), finding alliances or acquisition targets (Helfat et al., 2007), technology-based partnerships (Ettlie & Pavlou, 2006), the formation of R&D cooperation ties (Kudic, Pyka, & Sunder, 2016), and inter-firm collaborations to enhance a firm's core competencies (Lorenzoni & Lipparini, 1999).

Based on the above discussion and our prior work, we would argue that internal and external innovation capabilities are both at work in enhancing the use of innovation input resources and the transformation of innovation output into commercialization. As with other capabilities, internal and external innovation capabilities are likely to work in tandem (Laursen & Salter, 2006). A well-established approach argues that internal resources are a necessary condition for such absorption (Cohen & Levinthal, 1990). Generally, scholars tend to contend that the resources embedded in a business network complement a firm's internal resources and enhance its effectiveness and efficiency in new product development activities (e.g., Cassiman & Veugelers, 2006). This leads us to the following hypothesis:

H4. External and internal innovation capabilities are complements in enhancing innovation output.

2.4. Complexity as contingency

Innovation has been conceptualized as a process characterized by high uncertainty (Fagerberg, 2009; Nelson & Winter, 1982; Pavitt, 2009). Reflecting this, the literature on complexity highlights environmental dynamism as an important dimension of complexity, as "an increasing number of changing elements, interrelationships and exchange processes also increase in complexity" (Braun & Hadwich, 2016, p. 3512).

With respect to firm performance in general, complexity is found to be an important moderator of the strategy–performance relationship (McArthur & Nystrom, 1991) and to exhibit a curvilinear relationship with performance (Davis, Eisenhardt, & Bingham, 2009). Furthermore, the context in which the firm functions matter for innovation (Zahra, 1996), but also the product development process (Revilla et al., 2010), and the way opportunities are captured (Hsieh et al., 2007).

Based on the understanding of capability as "the ability to continuously transform knowledge and ideas into new products, processes and systems for the benefit of the firm and its stakeholder" (Lawson & Samson, 2001, p. 384), we expect that innovation capability plays a particularly salient role in the innovation process under conditions of higher complexity. We therefore state the following:

H5a. The mediating effect of innovation capabilities is stronger in more complex external environments.

How does complexity affect the function of innovation capability? Complexity in the processes of a firm would also be expected to act as a contingency on the role of innovation capabilities. Compare the following two cases. The first case includes a set of fairly straightforward inputs into an innovation process. In fact, creating innovation from these inputs requires less advanced dynamic capabilities, as the number of possible configurations and combinations is limited. Hence, firms with the same resources and different innovation capabilities would appear relatively similar. Contrast this with a case in which the resources are complex. The number of combinations increases and the difference between high and low levels of innovation capability becomes clearer. The firm with the highest innovation capability can seize and reconfigure a higher number of combinations and hence is more likely to succeed (Vasconcelos & Ramirez, 2011). We therefore suggest the following.

H5b. The mediating effect of innovation capabilities is stronger in more complex internal processes.

Continuing the preceding discussion of complementarity, we argue that complementarities between internal and external innovation capabilities are also relevant under varying levels of complexity. Two arguments stand out with respect to how complexity would influence the interaction between internal and external innovation capabilities. First, contextual complexity might foster an exploration orientation (Sidhu, Volberda, & Commandeur, 2004) in that firms are pioneering new uses of their capabilities (Sirmon, Hitt, & Ireland, 2007). In complex environments (i.e., dynamic environments), firms will consider a broader range of alternatives, resources, capabilities, and information sources, as well as efforts to integrate different approaches (Eisenhardt, 1989; Eisenhardt & Martin, 2000). Second, when facing the uncertainty that stems from increasing contextual as well as procedural complexity, managers are likely to search for information more broadly and comprehensively in order to mitigate the uncertainty (Daft & Weick, 1984). Consequently, we would expect complexity to enhance the effect of complementarities between internal and external innovation capabilities.

H5c. The mediating effect of complementarities between internal and external innovation capabilities increases under any type of complexity.

Fig. 1 depicts a summary of the different hypotheses. We will, in the following section, test the different relationships separately by adding variables one by one and sequentially testing the paths from input to output and then from output to commercialization. This takes the form of a regular regression analysis (Ordinary Least Square — OLS and logistic regression). We will also take special care to test the mediating relationship using Baron–Kenny mediation analysis with a quasi-Bayesian estimator. Both analyses, however, support the same findings.

3. Data and methods

To test our hypotheses, we use Eurobarometer 2009 "Innovation" (known as Innobarometer 2009) (European Commission, 2009), which is a survey of $N = 4466$ companies ($i \in [1, N]$) from $C = 30$ countries all over the EU ($c \in [1, C]$).

A key advantage of the Innobarometer 2009 survey is that it explicitly focuses on innovation as a general topic. Thus, innovation was the overall topic of the survey and not an auxiliary subtopic of a larger data collection. Furthermore, the Innobarometer 2009 survey was designed so that all firms received questions about inputs of the innovation process, outputs of the innovation process, and their organizational capacity to innovate. Unlike other surveys, this survey had no sample selection bias, with only innovators receiving questions about the

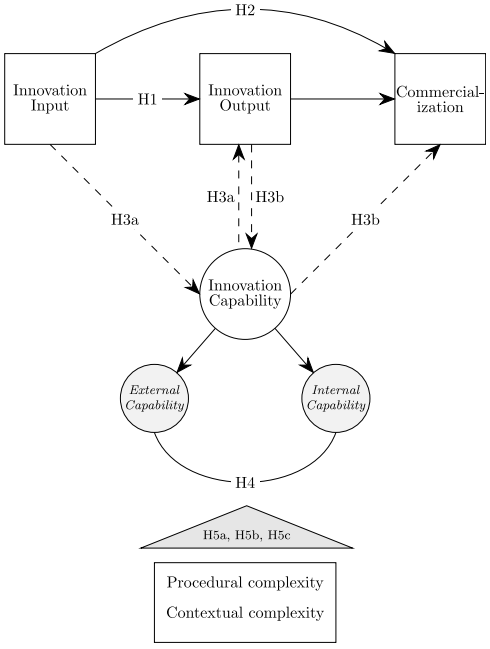

Fig. 1. Conceptual figure with prescribed hypotheses.

process or their organizational capacity for innovation. Furthermore, and critical for the purposes of our study, the Innobarometer 2009 included a set of questions that could be used to measure innovation as capability separately from measuring it as an input or outcome. Finally, the data set is rather similar in structure to other well-used sources, such as Community Innovation Survey (CIS) (Laursen & Salter, 2004, 2006), which lends a certain face validity to the use of this type of data in innovation research. This version of the barometer contained a set of questions appropriate for building empirical constructs of all the concepts in our conceptual model (see Fig. 1). The variables are described in Table 4. We use two dependent variables, *innovation output* (Y_i) and *commercialization* (G_i). Our main independent variables are *innovation input* (X_i) and *innovation capabilities* (internal (ξ_i) and external (ϕ_i)). Additionally, we used three (Z) firm-level controls (C_i^z): *firm size*, *firm age*, and whether the firm has international activities such as production or sales outside its home country (*international exposure*). These have all been empirically demonstrated to have a significant effect on innovation (Duran et al., 2015). The international exposure variable warrants a particular treatment: Empirical studies have found that firms competing globally across multiple regions face more demanding and diverse needs from their customers than do other companies (Penner-Hahn & Shaver, 2005). This leads to an increasing need for them to innovate (Aniruddha & Mital, 2016).

Most of the Innobarometer questions had binary answers. Typically, the respondents were asked to answer "yes" or "no" to questions about a range of different efforts they had made or results they had achieved.[1] One example is the question about what different types of measures had been taken to help the innovation of the firm. The respondents were given five different measures to which they responded "yes" or "no", depending on whether they had been implemented in the company. The binary structure of the data lends itself very well to *item response theory* (IRT). The goal of IRT is to determine the extent to which a series of true/false statements are able to discriminate between responses that are good or bad (de Boeck & Wilson, 2004). Its main application areas have traditionally been psychometric and education science, but recent contributions to management science have elevated its position in and applicability to strategic management research as well (Carroll et al., 2016).

While a full description of the empirical method is beyond the scope of this paper, a brief explanation seems warranted. The statistical technique enables us to measure the latent traits of individual observations based on how the participants respond to true/false questions. Using Markov-chain Monte Carlo (MCMC) models, we can solve the complex problem of identifying the discriminatory behavior underpinning a respondent's answers (see de Boeck & Wilson, 2004 for an introduction).

To test for the focal contingencies, we added a measure of external complexity using data from the Economic Complexity Observatory (Simoes & Hidalgo, 2011) of the MIT Media Laboratory. This data set has a well-tested metric for country-level complexity. Ideally, we wanted to add complexity at the industry level, but the existing data allowed only for product-level analysis and could not easily be transformed into industries in the aggregate. We then used the contextual complexity variable as a filter to draw a subsample of firms with a high degree of complexity (above one standard deviation from the mean). Analogously, for procedural complexity, we employed a metric for the number of different resources put into the innovation process. Similarly, we drew a subsample of firms with a high number of different resources in the innovation process (above one standard deviation from the mean).

3.1. Dependent variables

The first dependent variable, *innovation output*, is measured by the items described in Table 4. The respondents were asked to identify which offerings they had been able to achieve from their innovation activities. These offerings included new products, new services, improvements to existing products, organizational improvements, and new business models. Using IRT, we extracted a corresponding Z-value representing the level of output for each individual firm. Fig. 3 depicts two important diagnostic tools for determining the suitability of the scale created by IRT (the latent trait). The first is the *item characteristics curve* (ICC), which shows the relationship between the individual items in the scale and the latent trait (the scale) itself. A good scale should be increasing monotonously and be gathered around the mean of the latent trait. The second diagnostic is the *test information function* (TIF), which identifies the part of the population for which the latent trait provides the most information. If these curves exhibit a normal distribution, they are a proper representation of the mean (de Boeck & Wilson, 2004). From Fig. 3, it is clear that the latent trait of the output is a proper representation of our innovation output variable.

The second dependent variable is the business outcomes of innovation, *commercialization*, or innovation gain. We use commercialization as a shorthand term in this paper. This metric is a binary measure, with respondents receiving a score of 1 if half or more of their revenue stems from innovative products or services.

3.2. Independent variables

To measure the concept of innovation capability, we draw on Lawson and Samson, who have written a widely influential conceptual paper on this topic. While they state that "there is no clear agreement of what the real variables of innovation capability might be, and that there are likely to be disagreements" (Lawson & Samson, 2001, p. 389), a novel aspect of their article is that it provides guidance for how innovation capability can be measured empirically. In their conceptualization, innovation capability is a "higher-order integration

[1] Some respondents answered "not applicable" (NA), which we coded as zero. Answering NA signals that the type of innovation was not applicable to them due to the nature of their firm. Still, this also meant that the firm did not innovate in this dimension. To make sure that this coding did not alter the overall results, we ran robustness checks in which NA was coded as missing data. These checks did not materially alter the results.

capability, that is, the ability to mold and manage multiple capabilities" (ibid., p. 380). Drawing further on their work, we argue that such a higher-order innovation capability manifests itself in two lower-level capabilities oriented toward influencing internal and external innovation: external innovation capability and internal innovation capability. Importantly, the idea that innovative organizations need to master both internal and external innovation has been widely confirmed in the literature since Lawson and Samson's influential paper (e.g., Chesbrough, 2003; Laursen & Salter, 2006 and Clausen & Madsen, 2011), including the idea that important sources of innovation include not only customers and competitors but also sources such as universities, research institutions, and suppliers (Laursen & Salter, 2004; Lundvall, 1992; West & Bogers, 2014). Furthermore, Lawson and Samson argue that the following elements constitute important building blocks of innovation capability: "learning about customers", "learning about competitors", "creativity & idea management", "a permeable boundary that helps to break down barriers separating functions, groups and businesses", "communication, where cross-functional, cross-hierarchical, cross-cultural and cross-technological exchange of information and knowledge is important", and "management of technology, embracing the core idea that external networks are tremendously important and that innovative organizations leverage the entire corporate knowledge base". A novel feature of the Innobarometer 2009 data set is that it included questions about several of these important aspects of innovation capability discussed by Lawson and Samson. Thus, we used several questions from the Innobarometer 2009 to measure the external and internal dimensions of innovation capability in line with Lawson and Samson's conceptualization (see the Appendix for more details).

We use IRT to extract three independent variables in accordance with our research model. First, *innovation input* represents the resources and activities put into the innovation process, such as R&D, license purchasing, training to support innovation, and design. Second, *external innovation capability* includes measures that capture a firm's ability to search for and use innovation opportunities outside the firm and hence put external innovation inputs to use. Finally, *internal innovation capability* captures a firm's strategically developed competencies (e.g., personal skills and expertise, McKelvie & Davidsson, 2009, the ability to learn systematically, Zollo & Winter, 2002, and experimentation and learning, Eisenhardt & Martin, 2000). This includes items such as the ability to work in a team, negotiation skills, and creativity.

We entered the firms' size, age, and international activity as important control variables. These variables are included because the extant theorizing and empirical research highlight that these characteristics are positively correlated with innovation capacity and innovation outcome (Becheikh et al., 2006; Greve, 2003; Romijn & Albaladejo, 2002), which should not be conflated with the effect that innovation capability has on innovation outcome. First of all, past reviews have shown that size is a key determinant of innovation and related to a broad range of other organizational outcomes (Josefy, Kuban, Ireland, & Hitt, 2015). Reflecting this, size is considered to be "perhaps the most powerful explanatory organizational covariate in strategic analysis" (ibid., p. 715). Moreover, firms typically grow into becoming a large organization, typically through innovation (Audretsch, Coad, & Segarra, 2014). However, size is not the same as innovation capability, and we therefore distinguish their effects in our analysis. Further, organizational capabilities typically improve with age through learning and performance feedback (Withers, Drnevich, & Marino, 2011). Therefore, it is important to control for age so as to not confound the effect of age and the organizational capacity for innovation. Lastly, we control for interactional activity. International activity is a well-known correlate of innovation and has also been found to influence the innovation capacity of organizations (Kafouros, Buckley, Sharp, & Wang, 2008). However, international activity and innovation capability are two distinct phenomena. We therefore separate their effects by controlling for international activity in our analysis of the role of innovation capability. Moreover, including the abovementioned variables helps to control for survivor bias. Simply put, older and larger firms that are present in international markets have a track record of past accomplishments. But importantly, we should not confound the effect of past accomplishments when seeking to test the effect of innovation capability (Ambrosini & Bowman, 2009; Priem & Butler, 2001; Schilke et al., 2018; Williamson, 1999).

Please note that since the nature of innovation varies among industries and countries (Edquist, 2005; Malerba, 2005), we control for the fixed industry and country effects in our econometric analyses in the form of industry and country dummies. Table 4 in the Appendix offers more details on the construction of these variables. All variables in this study were scaled with a lower bound of zero for the purpose of interpretation, which follows from the IRT approach to latent variable construction (de Boeck & Wilson, 2004; Carroll et al., 2016). It does not affect the empirical results at all.

3.3. Descriptive statistics

Table 1 presents the pairwise correlations and the simple mean and standard deviation of each variable. Not surprisingly, innovation input and output are highly correlated with a coefficient of 0.514. Furthermore, our internal and external IC constructs are less strongly correlated, with a coefficient of 0.375. This suggests that they represent different concepts but that they are still related. In the empirical modeling, we took particular care to test for problems of multicollinearity, but we did not find any issues that affected the results.

4. Empirical estimates and results

The main analysis is a two-step regression model in which the first step estimates

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 \phi_i + \beta_3 \xi_i + \beta_4 (\xi_i \times \phi_i) + \Gamma C_i^Z + \epsilon_i \quad (1)$$

$$G_i = \gamma_0 + \gamma_1 X_i + \gamma_2 \phi_i + \gamma_3 \xi_i + \gamma_4 Y_i + \Lambda C_i^Z + \mu_i \quad (2)$$

where Y_i is *innovation output* and G_i is *commercialization*. Our main independent variables are *innovation input* (X_i) and *innovation capabilities* (internal (ξ_i) and external (ϕ_i)). Additionally, we use three (Z) firm-level controls (C_i^z): firm size, firm age, and whether the firm has international exposure. These are all estimated in two vectors of coefficients, Γ and Λ.

4.1. Regression results

As described above, we estimated this system separately using OLS for the first estimate and logistic regression for the second estimate. The results are given in Table 2. To maintain control of the individual effects, we sequentially added internal and external capabilities, as well as their interaction. In the second step, we regressed Eq. (2) by means of a logistic regression, with $G_i \in [0, 1]$. These first models lend support to all our hypotheses except H4b, concerning the complementarity between internal and external innovation capabilities. We also see that the coefficients of innovation input and innovation output in Eqs. (1) and (2), respectively, decline when our innovation capability variables are added. This suggests support for the mediation hypotheses.

In Table 2, Model 1 lends support to our first hypothesis about the positive relationship between input and output. This is not surprising given that these two are highly correlated. When the internal and external innovation capabilities are added, the coefficient of innovation input (β_1) drops from 0.474 to 0.389. Although still significant, this result supports a partial mediation by innovation input on innovation output through innovation capabilities. This lends support to H3a. Furthermore, we observe a similar characteristic regarding the coefficient of innovation output on commercialization (γ_4). This coefficient

Table 1
Descriptive statistics and correlations for variables in this paper.

	Mean	SD	1	2	3	4	5	6	7	8
(1) Input	1.20	0.75	1							
(2) Output	1.11	0.73	0.513	1						
(3) Internal IC	0.87	0.69	0.34	0.415	1					
(4) External IC	0.78	0.69	0.445	0.434	0.375	1				
(5) Total IC	1.12	0.77	0.431	0.486	0.949	0.63	1			
(6) Firm size	1.94	0.97	0.277	0.174	0.19	0.156	0.216	1		
(7) Firm age	0.08	0.28	0.01	0.038	0.016	0.04	0.023	−0.039	1	
(8) International exposure	0.47	0.50	0.259	0.165	0.108	0.18	0.146	0.178	0.006	1

Notes: Pairwise correlations between variables in the study including controls.

Table 2
Regression results for relationships between input, output and commercialization.

	Dependent variable:						
	Innovation output					Commercialization	
	OLS					*logistic*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Innovation input	0.474***	0.389***	0.368***	0.324***	0.330***	0.383***	0.290***
	(0.013)	(0.013)	(0.014)	(0.014)	(0.014)	(0.086)	(0.089)
Innovation output						0.300***	0.174*
						(0.098)	(0.103)
		(0.014)		(0.014)	(0.020)		(0.093)
External IC			0.258***	0.194***	0.215***		0.263***
			(0.014)	(0.014)	(0.023)		(0.090)
Firm size	0.028***	0.008	0.022**	0.007	0.008	−0.138**	−0.158***
	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.056)	(0.057)
Firm age	0.070**	0.060*	0.051	0.047	0.046	0.224	0.208
	(0.033)	(0.031)	(0.032)	(0.031)	(0.031)	(0.172)	(0.173)
International exposure	0.062***	0.048**	0.031*	0.033*	0.033*	0.189	0.164
	(0.020)	(0.019)	(0.018)	(0.018)	(0.019)	(0.117)	(0.117)
Internal IC × External IC					−0.022		
					(0.019)		
Constant	0.364***	0.351***	0.362***	0.316***	0.289***	−2.596***	−2.668***
	(0.091)	(0.087)	(0.048)	(0.047)	(0.086)	(0.481)	(0.484)
Country Fixed Effects	YES	YES	YES	YES	YES	YES	YES
Industry Fixed Effects	YES	YES	YES	YES	YES	YES	YES
Firms included	All	All	All	All	All	All	All
Pseudo R^2						0.053	0.02
Observations	4688	4688	4693	4693	4688	3592	3592
R^2	0.306	0.362	0.345	0.382	0.386		
Adjusted R^2	0.300	0.356	0.340	0.378	0.380		

*p < 0.1.
**p < 0.05.
***p < 0.01.

drops considerably, from 0.300 to 0.174, providing support for H3b. We pursue this further in the next section when formally testing for mediation.

The coefficient of innovation input on commercialization is also positively significant and robust to the inclusion of industry and country dummies, as well as controls and innovation capabilities. This lends support to H2.

One surprising result, however, is that the internal and external capabilities do not exhibit complementarity, as evident from their insignificant interaction (β_4). Consequently, we find no support for H4. The findings in the mediation analysis, however, shed some light on this finding.

4.2. Mediation analysis under different levels of complexity

To formally test the mediation effects and investigate their contingency conditions (i.e., under contextual and procedural complexity), we employ a quasi-Bayesian estimation of the Baron–Kenny method for mediation analysis (Baron & Kenny, 1986; Hicks & Tingley, 2011). We estimate the mediating effects of internal, external, and total innovation capabilities, as well as the interaction between internal and external innovation capabilities. The system of equations can be written as follows:

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 M_i^R + \Gamma C_i^Z + \epsilon_i \quad (3)$$

$$M_i^R = \gamma_0 + \gamma_1 X_i + \gamma_4 \Lambda C_i^Z + \mu_i \quad (4)$$

where Y_i is *innovation output* and M_i^R is a vector of our four mediators (internal, external, and total innovation capabilities, as well as the interaction between internal and external capabilities). Our main independent variable remains *innovation input* (X_i). Additionally, we use three (Z) firm-level controls (C_i^z): firm size, firm age, and whether the firm has international exposure. These are all estimated in two vectors of coefficients, Γ and Λ. In total, this yields four models, which are run under three different conditions (as represented by different samples of firms): the base case with a full sample (i.e., the average of all the firms with respect to complexity), a subsample of firms with high levels of procedural complexity, and a subsample of firms with high levels of contextual complexity. Then, in the special case of interactions between internal and external innovation capabilities, we add the total innovation capability as a control (not shown in the system of equations).

The results of this analysis are presented in Fig. 2. All effects are significant. All mediation effects are stronger (i.e., they account for a larger share of the total effect of innovation input on innovation output)

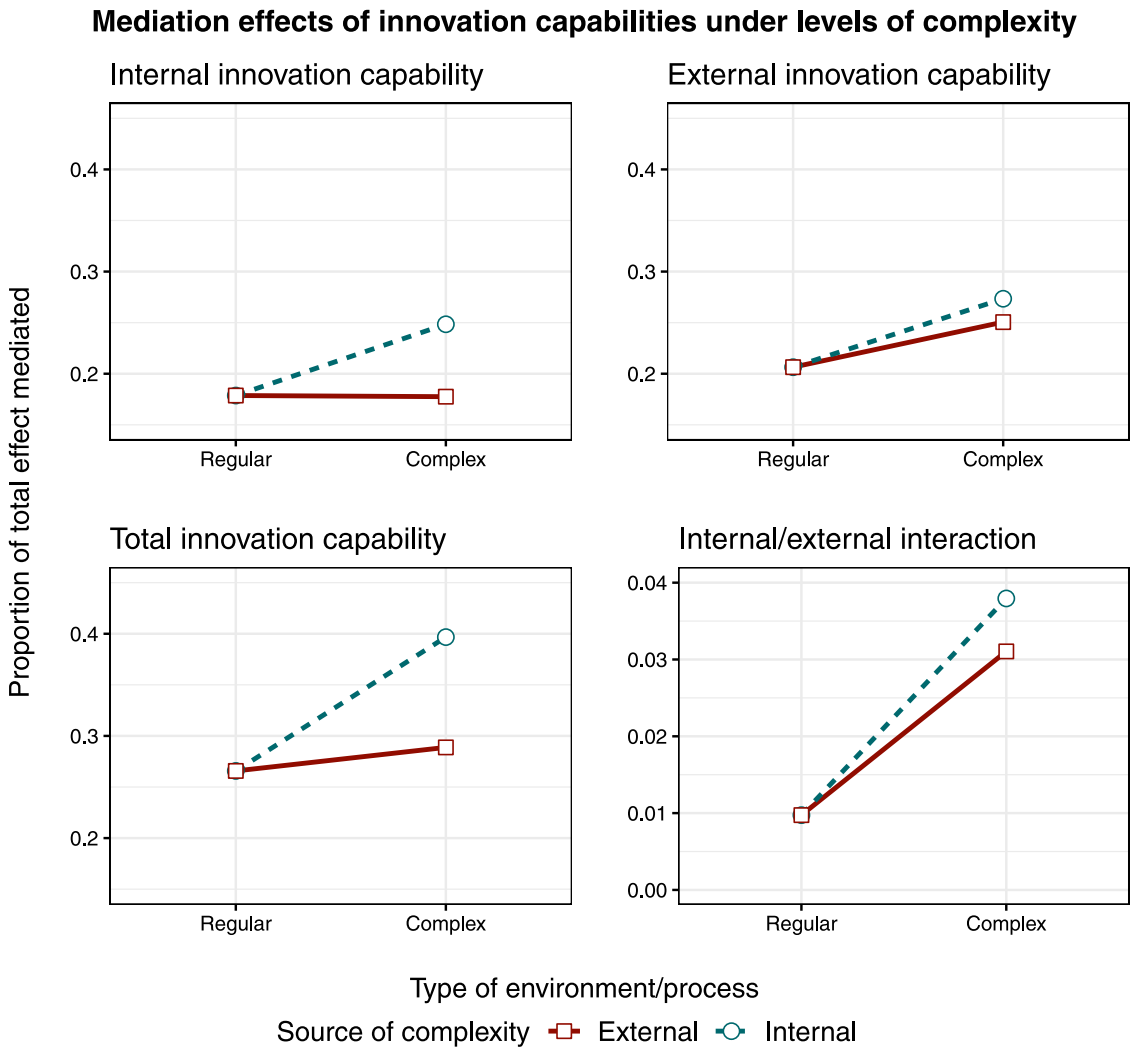

Fig. 2. Mediation analysis under different levels of complexity. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

for firms facing contextual and procedural complexity. Generally, the firms leverage high levels of procedural complexity better than high levels of contextual complexity. This is evident by the larger slope of the blue dotted lines in all the mediators. There are differences between the mediators, however. Internal innovation capability (the model at the top left) works better at mediating innovation input to innovation output under conditions of high procedural complexity, whereas contextual complexity plays a fairly insignificant role. Looking at the external innovation capabilities (at the upper right), we see a different pattern. This supports H5a.

External innovation capability works better as a mediator under both types of complexity and even slightly better under contextual complexity. The difference is, however, so small that it is hard to draw firm conclusions. Hence, we contend that this lends weak support to H5b.

Not surprisingly, we find that the total innovation capabilities (as a function of both internal and external capabilities) exhibit an average pattern in which both contextual and procedural complexity enhances their mediating effects.

Finally, in the lower-right model, the complementarities between internal and external innovation capabilities exhibit a similar pattern. Recall that this model controls for the total innovation capability, so the observed effect is much lower than in the other models, as it only accounts for a residual effect above and beyond the effect of the total innovation capability (which is evident from the small scales on the y-axis). Note that only the contextual complexity significantly enhances the mediation of the complementarities. The effect of procedural complexity is insignificant. This result, therefore, lends only partial support to H5c.

Table 3
Hypotheses and findings summarized.

Hypothesis	Finding
H1	Support
H2	Support
H3a	Support
H3b	Support
H4	No support
H5a	Support
H5b	Weak support
H5c	Partial support

Table 3 summarizes the findings of this analysis. We find support for all our hypotheses except for H4b. We also find only partial support for H5b and H5c.

5. Discussion and future research

In this paper, we included the strategic management concept of innovation capability as "an ability to continuously transform knowledge

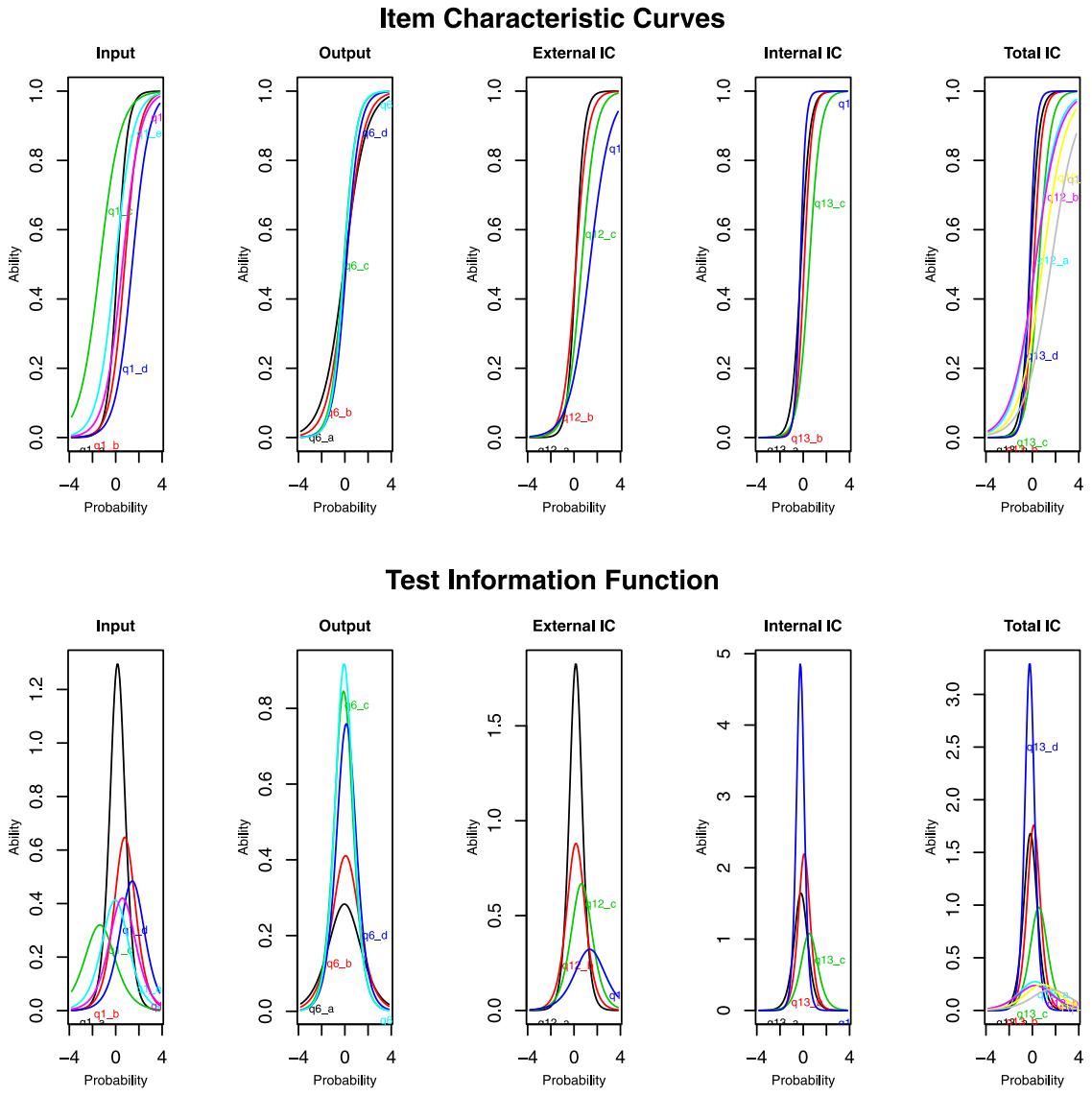

Fig. 3. Characteristics and information evaluations from latent traits.

and ideas into new products, processes and systems for the benefit of the firm and its stakeholders" (Lawson & Samson, 2001, p. 384) in the innovation process and examined whether and how it influenced the innovation outcomes. We theorized how firms differ not only with respect to their investment in innovation inputs but also in their ability to convert these inputs into output and ultimately create value in the form of commercialization. A key contribution of the paper is the development of a mediation model to test how innovation capabilities act to enhance the conversion of innovation input into innovation output and how this process is contingent on the procedural and contextual complexity facing a firm. Firms that have developed such innovation capabilities are better at creating innovation output *et ceteris paribus* and are at least partially able to enhance the effect of innovation input. We find empirical support for such a partial mediation hypothesis.

Similarly, we find support for a full mediation between innovation output and commercialization. This suggests that innovation capabilities contribute to higher levels of commercialization and value creation from innovation. This notion is consistent with recent literature suggesting that the capability for innovation enhances the development of a business model (Teece, 2017). We theorized a distinction between internal and external innovation capabilities and suggested that they are separate constructs, but they did not act as complements as we expected. The interaction effect in the empirical model was not significant, lending no support to our hypothesis.

Our theoretical discussion of the contingencies of the mediation relationships suggested that innovation capabilities in general would work better under a higher level of complexity. We distinguished between contextual and procedural complexity and, using subsamples, tested shifts in the mediating relationships of innovation capabilities (internal, external, total, and their interaction). In line with previous empirical findings on environmental dynamism (Schilke, 2014), we find empirical support for complexity affecting the theorized relationships. This finding also makes intuitive sense. If a firm is better at exploiting opportunities than its competitors, we would expect it to do also better than its peers when complexity increases.

Overall, our theorizing, along with the model and the empirical results, initiates an important discussion about whether and how the capacity of an organization for innovation influences innovation as a process and innovation as an outcome (Kahn, 2018). Our entry point into this debate was to conceptualize the capacity of an organization for innovation as innovation capability (Breznik & Hisrich, 2014; Lawson & Samson, 2001; Saunila, 2019). While the role of innovation capability in innovation as a process and innovation as an outcome is implicit in the extant research and theories (Crossan & Apaydin, 2010; Mir

et al., 2016), it is important to avoid confusing a capacity for innovation with innovation as a process or an outcome (Kahn, 2018). Therefore, relationships must be made explicit so that they can be empirically tested, criticized, and extended. Such a development is key to building cumulative knowledge about the role of innovation capability in the innovation process and how it shapes its outcome.

One way to help build explicit cumulative knowledge about innovation capability is to firmly place the concept within a clear theoretical framework. Arguably, the concept of innovation capability currently has no explicit theoretical home. Scholars, however, who have implicitly theorized about the role of innovation capability, such as Teece (1986, 2007, 1997), can be regarded as the "founders" of the theory of dynamic capabilities (Helfat et al., 2007; Schilke et al., 2018). Placing innovation capability firmly within this theoretical framework opens up new avenues for understanding whether and how the capacity of an organization influences its innovation processes and outcomes. One important implication is that innovation can be considered a key functional domain of dynamic capabilities (Breznik & Hisrich, 2014; Schilke et al., 2018). Arguably, conceptualizing innovation capability as a (key) functional domain of dynamic capabilities goes in line with the extant conceptualization of innovation capability as "a higher-order integration capability, that is, the ability to mold and manage multiple capabilities" (Lawson & Samson, 2001, p. 380). While such connections have been hinted at in the literature (e.g., Breznik & Hisrich, 2014; Lawson & Samson, 2001), few attempts have been made so far to provide explicit connections. Our mediation model, however, represents a point of departure for making relationships between innovation capability – as a dynamic capability – and innovation as a process or innovation as an outcome more explicit. A key finding in this regard is that innovation capability partially mediates the crucial relationship between innovation input and innovation output that extant research has documented (Baregheh et al., 2009; Meissner & Kotsemir, 2016; Rothwell, 1994; Saunila, 2019). Moreover, and perhaps equally interesting, we find that such capabilities become more valuable when firms are faced with increasing levels of complexity, suggesting that some firms are not only better at innovation as a process but also better at maneuvering the complexity (e.g., playing 3D chess in the initial analogy from "The Big Bang Theory"). Together, this suggests that innovation capability matters and that it is distinct from innovation as a process or an outcome.

The paper uncovers that innovation capabilities can be decomposed into internal and external innovation capabilities. The findings suggest that these are separate but related concepts and that they both relate to the total capabilities of a firm to enhance innovation output and commercialization. Strikingly, however, both concepts become more relevant and valuable (their mediating effect increases) when firms are faced with higher levels of complexity. We find that when internal complexity increases, the value of internal capabilities also increases. This finding suggests that knowledge management systems, team working capacities, and internal mechanisms for idea sharing become more important when internal complexity increases. The same goes for external complexity and external capabilities. However, for external capabilities, we observe that they also increase in value when internal complexity increases. This is not the case the other way around. One possible explanation is leakage of knowledge within a firm (Galati, Bigliardi, Petroni, Petroni, & Ferraro, 2019), suggesting that such leakages are more common in more complex organizations simply because of the challenges in monitoring and controlling knowledge spillovers. We suggest that when firms have well-aligned strategic relationships with suppliers, researchers, and customers, they are able to leverage these capabilities when complexity increases both outside and within the firm. This suggestion is also consistent with the view of open innovation (Laursen & Salter, 2006; West & Bogers, 2014) and technology transfer (Ferraro & Iovanella, 2015, 2017). Moreover, these findings also add to the emerging distinction between hierarchical and heterarchical models of organizing innovation (Cinelli, Ferraro, & Iovanella, 2019) and enable richer insights into the innovation process as shaped by external ties and networks.

Perhaps the most striking finding, and with considerable practical implications, is that internal and external innovation capabilities are not complementary. That is, besides the effects being very small, we find no significant interaction between internal and external capabilities. This suggests that firms need to invest cautiously in both types in order to achieve a full innovation capability and leverage the complexities in the firm and its environment. This finding paves the way for further research into how firms combine these apparently separate capabilities in their innovation process. It also adds a possible link to the larger literature on higher-order (dynamic) capabilities (Breznik & Hisrich, 2014; Schilke et al., 2018), in which combinations of capabilities can be seen as bundles, with higher-level properties geared at changing underlying routines (Winter, 2003). Complementarities might exist in certain firms under certain conditions, and these characteristics may be similar to dynamic capabilities, often defined as the full ability to sense and seize opportunities and to transform resources to make them viable (Teece, 2007).

Our research also has implications for the literature on "profiting from innovation", arguably initiated by Teece's seminal article (1986). Our theorizing, as displayed in the mediation model and the empirical results, shows that innovation capability partially mediates the relationship between innovation output and commercialization. This result extends the extant research showing that firm management can influence not only the relationship between innovation input and innovation output (Duran et al., 2015) but also the relationship between innovation output and the rewards that firms can reap in the commercialization stage of the innovation process.

Thus, overall, our theory and model explicitly highlight three key mechanisms through which innovation capabilities influence the innovation process: (i) influencing the relationship between innovation input and innovation outcome, (ii) influencing the relationship between innovation outcome and commercialization, and (iii) strengthening these relationships in the presence of increasing complexity. Arguably, these mechanisms extend our understanding of the role of innovation capability in the innovation process and in the value created from innovation at the firm level.

6. Concluding remarks and limitations

We began this paper with an appropriate statement: "Strategic management scholars seem to agree that there exists a positive relationship between input and output in the innovation process, and the 'slope' of this relationship likely differs among organizations because of the complexity of innovation management" (Duran et al., 2015, p. 1227). In other words, firms differ not only in their level of innovation input (e.g., R&D) but also in their efficiency in converting said input into output. We wanted to investigate this relationship by incorporating innovation capabilities into the analysis of firm innovation processes.

We theorized about how innovation capabilities, both internally and externally oriented, are designed to orchestrate resources for innovation and hence influence the innovation outcome. Innovation capabilities are thus theoretically related to dynamic capabilities in that they act to modify other resources for a strategic end. We found partial support for the mediating effect of innovation capabilities between innovation input and innovation output but less clear evidence for a mediating effect between innovation output and commercialization.

Our results suggest, however, that firms are able to harness innovation capabilities to generate innovation output and that the effect is partially determined by the level of input in the innovation process. Specifically, innovation capabilities can provide a partial answer to how innovation input becomes innovation output and, consequently, value creation.

A promising line for future research is to study whether and to what extent innovation capabilities have the same or different effects

Table 4
Variable description.

Type	Variable name	Measurement	Content
Dependent	Innovation Output (Y_i)	Continuous	Item response Z-scores • New or improved products • New or improved services • New or improved processes • New or improved marketing strategies • New or improved organizational structure
Dependent	Commercialization (G_i)	Binary	Indicating if main share of sales attributed to innovation • Most sales came from innovative products or services ($G_i = 1$)
Independent	Innovation Input (X_i)	Continuous	Item response Z-scores *Has your company had expenditures on any of the following activities to support innovation since 2006?* • R&D within your company • R&D performed for your company by other enterprises or by research organizations • Acquisition of new or significantly improved machinery, equipment and software • Purchase or licensing of patents, inventions, knowhow, and other types of knowledge • Training to support innovative activities • Design (graphic, packaging, process, product, service or industrial design) • Application for a patent or registration of a design
Independent	External capabilities (ξ_i)	Continuous	Item response Z-scores *Since 2006, has your company developed any strategic relationships in support of your innovation activities with (any of the following):* • Some specific customers or clients • Suppliers • Other companies active in your field • Research institutes • Educational institutions
Independent	Internal capabilities (ϕ_i)	Continuous	Item response Z-score *Since 2006, has your company started or increased any of the following initiatives to integrate different company activities in support of innovation:* • Knowledge management systems • Internal mechanisms for employees to submit innovative ideas • Staff rotations or secondments between different functions • Creation of cross-functional or cross-departmental teams on innovation projects • Team working capacity • Negotiation skills • Ability of successful communication with people of other culture • General communication skills • Creativity (e.g. problem-solving, originality of thought)
Independent	Innovation capabilities ($f(\xi_i, \phi_i)$)	Continuous	Item response Z-score of all items under ξ_i and ϕ_i
Control	Firm size (C_i^S)	Ordinal	Scale of size from 20 to > 500 in 4 steps
Control	Firm age (C_i^A)	Binary	Indicate if firm is established before 2001 ($C_i^A = 1$)
Control	International exposure (C_i^E)	Binary	Indicate if firm produce or sell products outside own country ($C_i^E = 1$)
Filter	Contextual complexity (F_1)	Binary	Indicate if firm is located in a high complexity country environment
Filter	Procedural complexity (F_2)	Binary	Indicate if firm has complex innovation input

on different types of innovation. This is, in our opinion, a natural progression from the research conducted in our paper. Indeed, innovation comes into types, such as process innovation, product innovation, organizational innovation, and marketing innovation. A limitation in our paper is that we did not differentiate between these types of innovations. The data set we have access to is not detailed enough to probe into the nature of more nuanced relationships. However, doing so with richer data holds the promise of further unlocking the role of innovation capabilities in the innovation process. Therefore, research that probes deeper into the nature of the relationship between innovation capability and different types of innovation should be high on the agenda of researchers interested in the role of innovation capability.

Drawing too broad conclusions is problematic, however. We have built our empirical analysis on a single source of data, an approach that is prone to common-method bias. Furthermore, the Innobarometer includes self-reported scores that were not validated in this paper. It is a large, cross-sectional sample that yields robust results. The same data set, however, has been used in other research papers (Arundel, Bloch, & Ferguson, 2019), and a similar survey (the Community Innovation Survey) has been used extensively (Blind, 2012; Keupp et al., 2012; Laursen & Salter, 2004, 2006). This lends a certain face validity to the data, but one should refrain from making broad generalizations. Finally, the data set captures only one moment in time, so robust techniques, including instrumentation for causal investigations, are impossible to apply and should be carried out in future research.

Limitations aside, we argue that this paper has nonetheless contributed to our understanding of how dynamic capabilities enable firms to innovate. We show that innovation output is a function of innovation input, as predicted by theory, and that this relationship is mediated by innovation capabilities. This leads us to suggest that firms can indeed obtain better innovation results by doing more of what matters, rather than just doing more.

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Appendix

See Fig. 3 and Table 4.

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