R&D MANAGEMENT

How to leverage the impact of R&D on product innovation? The moderating effect of management innovation

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Although research and development (R&D) is a key indicator of (technological) innovation, scholars have found mixed results regarding its effect on product innovation and firm performance. In this paper, we claim that variations in R&D effectiveness can be explained by changes in a firm's social system, in particular in its management innovation. It is still unclear how management innovation influences R&D effectiveness in terms of product innovation. In this study, we address this theoretical and empirical gap in the innovation literature. Our theoretical arguments and findings from a large-scale survey among Dutch firms show that R&D has a decreasingly positive relationship with product innovation, particularly for firms with low levels of management innovation. However, in firms with high levels of management innovation, this relationship becomes more J-shaped, especially in small and medium-sized firms. Our findings also appear to indicate that management innovation may be more important for competitive advantage than just R&D. Overall, our insights reveal that management innovation is a key moderator in explaining firms' effectiveness in transforming R&D into successful product innovation.

1. Introduction

Research and development (R&D), and indeed innovation in general, is typically considered to be a cornerstone of competitive advantage (e.g., Schumpeter, 1942; Armbruster et al., 2008; Teece, 2010), particularly for long-term success (Bravo and Reguera-Alvarado, 2017). Considerable attention has been given to technological innovation, which is the generation of new technological knowledge (inventions) and the market introduction of these inventions via new products or services (product innovation) (Utterback, 1971; Volberda et al., 2013; Damanpour, 2014). Investment in R&D is one of the most frequently used indicators of technological innovation (e.g., Coombs and Bierly, 2006; Raymond and St-Pierre, 2010; Volberda et al., 2013). This is hardly surprising because the term innovation is 'predominantly linked to the research and development (R&D) associated with creating new products' (Armbruster et al., 2008, p. 644).

However, the precise nature of the relationship between R&D and product innovation and firm performance is still rather unclear (Coombs and Bierly, 2006; Artz et al., 2010). Scholars have found positive relationships between R&D and either product innovation or firm performance (e.g., Baumann and Kritikos, 2016; Anzola-Román et al., 2018). They have also found relationships that are curvilinear, i.e., decreasingly positive (Erden et al., 2014) or U-shaped (e.g., Artz et al., 2010), non-significant (e.g., Raymond and St-Pierre, 2010), or even negative (e.g., Coombs and Bierly, 2006). The extent to which a firm introduces radical new products, i.e., product innovation, is argued to mediate the impact of R&D on firm performance (e.g., DeCarolis and Deeds, 1999). Product innovation is a crucial measure of a firm's R&D effectiveness, as it indicates how effectively it is using new technological knowledge (Coombs and Bierly, 2006; Cruz-Cázares et al., 2013).

R&D is related to changes in a firm's technical system. From a socio-technical systems perspective (Trist, 1981), variations in the effect of changes to the technical system may be explained by changes in a firm's social system (e.g., Damanpour, Walker and Avellaneda, 2009; Damanpour and Aravind, 2012; Azar and Ciabuschi, 2017). Management innovation is associated with changes in a firm's social system (Damanpour, 2014; Černe, Kaše and Škerlavaj, 2016), and has been defined as 'the generation and implementation of a management practice, process, structure, or technique that is new to the state of the art and is intended to further organizational goals' (Birkinshaw, Hamel and Mol, 2008, p. 829). Management innovation may complement the effect of technological innovation on firm outcomes (e.g., Damanpour et al., 2009; Damanpour, 2014) by providing a more fruitful organizational context that allows technological knowledge to be integrated and used more effectively (e.g., Benner and Tushman, 2003; Černe et al., 2016; Hervas-Oliver et al., 2018).

Nonetheless, when scholars are examining the performance effect of R&D or technological innovation in general, they often do not take into account the role of management innovation (e.g., Crossan and Apaydin, 2010; Volberda et al., 2013; Hervas-Oliver et al., 2018). Recently, some scholars have examined how introducing technological innovation and management innovation either simultaneously (e.g., Damanpour et al., 2009; Hervas-Oliver and Sempere-Ripoll, 2015; Hervas-Oliver et al., 2018) or sequentially (e.g., Mol and Birkinshaw, 2009; Azar and Ciabuschi, 2017) drives firm performance. However, studies on how both types of innovation affect firm performance when used in combination have typically ignored variations in firms' effectiveness at transforming R&D into radically new products. Consequently, insufficient attention has thus been given to whether the use of management innovation can explain the mixed findings in previous studies as regards the effect of R&D on product innovation and firm performance.

In addition, the precise nature of the combined effect of technological innovation and management innovation is still rather under-researched empirically (Azar and Ciabuschi, 2017; Magnier-Watanabe and Benton, 2017; Khosravi et al., 2019), especially with regard to nonlinear effects. The few scholars (e.g., Krzeminska and Eckert, 2016; Carboni and Russu, 2018; Hervas-Oliver et al., 2018) who have assessed empirically the combined effect of these two types of innovation have typically looked at the impact on firm performance and used dichotomous scales to measure both types. Using such binary adopt/do-not-adopt measures provides rather limited information on the differing degrees of intensity with which R&D and management innovation are introduced over a certain timespan. Taking those differing intensities into account is required 'to generate viable estimations' (Armbruster et al., 2008, p. 655) of their performance effects (Walker, Chen and Aravind, 2015; Hervas-Oliver et al., 2018; Romano, 2019). This would enable one to assess empirically whether there are nonlinear effects when R&D and management innovation are combined, because looking for complementarities by examining only linear effects 'may be misleading' (Bloom, Sadun and Van Reenen, 2010, p. 129). As yet, however, there have been no accurate empirical estimates of how management innovation may influence R&D effectiveness in ways that go beyond linear relationships. This brings us to the following research question: *Does management innovation moderate the relationship between different levels of R&D and product innovation?*

By addressing this research question, we contribute to a better theoretical understanding of the relationship between R&D and product innovation and we provide some empirical insights into whether management innovation influences that relationship. First, we shed new theoretical light on how management innovation – as a moderator – explains variations in R&D effectiveness. For example, our theoretical arguments reveal that, all other things being equal, a curvilinear (i.e., decreasingly positive) relationship between R&D and product innovation (e.g., Acs and Audretsch, 1988; Graves and Langowitz, 1993; Artz et al., 2010) is likely to be found especially in firms with low levels of management innovation. We also argue that when firms have high levels of both R&D

and management innovation, this will have complementary effects on product innovation. These conceptual insights advance our understanding of how both R&D and management innovation are related to firm outcomes.

Second, using a large-scale survey, we make an empirical contribution by assessing the extent to which differing levels of both R&D and management innovation affect product innovation. We found a curvilinear relationship between R&D and product innovation for firms with low levels of management innovation. This finding indicates that merely investing more in R&D results in suboptimal returns. These suboptimal returns can be offset by combining R&D with high levels of management innovation, which seems to be at least as important as R&D for enhancing product innovation. When non-technological innovation of this kind is used, the curvilinear relationship between R&D and product innovation becomes more J-shaped. A nonlinear relationship of this type also suggests that when firms, especially small and medium-sized firms, start to invest more in R&D and management innovation, they may experience a temporary reduction in product innovation.

In the next section, we review the existing literature and develop hypotheses on the relationship between R&D and product innovation, including the contingent role of management innovation. We then present our research method and analyses. Finally, we present our main empirical findings and discuss the implications and limitations of our study.

2. Literature and hypotheses

2.1. (Technological) innovation

Innovation is a complex and multifaceted concept (e.g., Damanpour and Aravind, 2012; Walker et al., 2015). It has often been divided into two types: technological and non-technological (e.g., Damanpour et al., 2009; Teece, 2010). Technological innovation is associated with changes in a firm's technical system or technical core, which comprises the primary work activities of an organization (Damanpour and Evan, 1984; Walker et al., 2015). It is about generating and applying new technological knowledge of how to do things differently and better in terms of a firm's products and services or its operational processes (Crossan and Apaydin, 2010; Barge-Gil and López, 2014). Investment in R&D is about generating new technological knowledge of how to do things differently and better (Chesbrough, Di Minin and Piccaluga, 2013; Barge-Gil and López, 2014; Erden et al., 2014). Even at low levels of R&D, small-scale experiments are a relatively inexpensive and quick way to generate new technological knowledge that may lead to product innovation (e.g., Pisano, 1994).

Product innovations are new products or services introduced to the market to serve market needs or developed to meet the needs of external customers (Jansen et al., 2006; Carboni and Russu, 2018). These innovations, which are aimed at new markets and customers, typically incorporate new knowledge that is very different in nature from most of its knowledge base (Benner and Tushman, 2002; Danneels, 2002). Compared to technological process innovation or product modification, the value of product innovation (which entails radical rather than incremental change) is typically less difficult to measure (Haneda and Ito, 2018).

New technological knowledge acquired through R&D is not identical to product innovation but is an input for it (e.g., Danneels, 2002; Cruz-Cázares et al., 2013). Coombs and Bierly (2006) argue that, in theory, the number of new products introduced by a firm may be one of the best measures of output, particularly when R&D is used as an input measure. The newly generated technological knowledge needs to be transformed or incorporated into innovative new products that are subsequently introduced into the market (Garcia and Calantone, 2002; Bergek et al., 2008). Such transformation and incorporation is about integrating the new technological knowledge into a firm's existing knowledge base (e.g., Nerkar and Roberts, 2004; Zhou and Li, 2012) and utilizing that knowledge (e.g., Zahra and George, 2002; Zhou and Wu, 2010). This process of integration allows a firm to internalize what it has learned and to alter its knowledge base (Zahra et al., 2000). It can, for instance, help a firm to connect knowledge that is dispersed across the organization and to connect new and existing knowledge in novel and valuable ways (Laursen, 2012). The term 'integration' is associated with 'combination' or 'configuration' (Van den Bosch, Volberda and De Boer, 1999), which is a key managerial task (e.g., Sirmon et al., 2011).

2.2. Relationship between R&D and product innovation

Initially, R&D broadens a firm's knowledge base (Zahra et al., 2000) by bringing in various forms of new knowledge (Wu and Shanley, 2009) and combining it with existing knowledge (Zahra et al., 2000;

Ahuja and Lampert, 2001). This provides more and better opportunities to create useful combinations of knowledge (Kogut and Zander, 1992; Katila and Ahuja, 2002; Laursen, 2012) that can be used to realize product innovation (Zahra and George, 2002; Zhou and Wu, 2010).

In addition, R&D can also bring about major changes in a knowledge base and can revise the frame of reference for a firm (Zahra and Chaples, 1993), i.e., reshape its knowledge base. Revising existing knowledge is in line with double-loop learning (Argyris and Schön, 1978), which is beneficial for product innovation (e.g., Holmqvist, 2003; Forsman, 2009). New technological knowledge that challenges a firm's beliefs and core assumptions enables a firm to rethink and renew its operational processes and routines (e.g., Forsman, 2009; Wu and Shanley, 2009) and drives it to recognize new opportunities for product innovation (Foss, Lyngsie and Zahra, 2013).

However, we argue that, beyond a certain point, less of the new technological knowledge acquired through R&D is actually used, resulting in fewer product innovations (cf. Acs and Audretsch, 1988; Graves and Langowitz, 1993). Integrating a greater amount of new technological knowledge and converting it into product innovation is more demanding, complicated and expensive, and may involve the use of more advanced and sometimes conflicting forms of integration (e.g., Grant, 1996; Chesbrough et al., 2013; Erden et al., 2014). Consequently, as the level of R&D increases, less of the new technological knowledge that is acquired is integrated and utilized, resulting in fewer product innovations (Acs and Audretsch, 1988; Levinthal and March, 1993; Ahuja and Lampert, 2001). With high levels of R&D, there are also fewer opportunities to combine technological knowledge with existing knowledge in ways that will be beneficial (Ahuja and Lampert, 2001; Laursen, 2012).

The sheer volume of new technological knowledge at high levels of R&D also reduces a firm's ability to respond properly to that new knowledge (Katila and Ahuja, 2002). Firms have a limited capacity for absorbing and integrating new technological knowledge (Erden et al., 2014). Beyond a certain point, large amounts of new technological knowledge can lead to confusion (Ahuja and Lampert, 2001), reduced creativity (Graves and Langowitz, 1993), increased conflict (Wu and Shanley, 2009), and organizational inertia (Zhou and Wu, 2010). This is partly due to the fact that, by generating new technological knowledge through high levels of R&D, a firm acquires knowledge that is different from and may conflict with its existing knowledge, activities and routines (Benner and Tushman, 2002, 2003; Wu and Shanley, 2009; Zhou and Wu, 2010). Cognitive and behavioral constraints and barriers may mean that fewer product innovations are achieved from high levels of R&D (Benner and Tushman, 2003; Wu and Shanley, 2009). Building on prior research (e.g., Graves and Langowitz, 1993; Wu and Shanley, 2009), we come to the following hypothesis;

> H1: *There is a curvilinear (i.e., decreasingly positive) relationship between R&D and product innovation.*

2.3. R&D and product innovation: the moderating effect of management innovation

Building on literature relating to the socio-technical system theory (Trist, 1981), we would expect changes in a firm's technological system (technological innovation) to be accompanied by changes in its social system (social innovation)[1] designed to improve firm outcomes (e.g., Damanpour and Aravind, 2012; Carboni and Russu, 2018). Both contribute to the innovation process in different ways (Daft, 1978; Kimberly and Evanisko, 1981). Introducing one without the other means that complementary effects between them are lost (Wischnevsky and Damanpour, 2006) and that the socio-technical system as a whole and hence firm outcomes are suboptimized (Damanpour et al., 2009; Damanpour and Aravind, 2012). The essence of complementarity, according to Milgrom and Roberts (1995, p. 181), is that 'doing *more* of one thing *increases* the returns to doing *more* of another' (italics in original).

Management innovation is associated with changes in a firm's social system. Although it is related indirectly to a firm's primary work activities, it is related more directly to changes in the way management performs its work (Damanpour, Szabat and Evan, 1989; Hamel, 2006; Černe et al., 2016). Management innovation is typically more diffuse and gradual than technological innovation, and more contingent upon actors and relationships within the organization's highly complex social system (Birkinshaw and Mol, 2006). It is typically also less discrete and tangible, more organization-specific, and more difficult to replicate than technological innovation (e.g., Hamel, 2006; Evangelista and Vezzani, 2010). These particular characteristics make it potentially more valuable than technological innovation (e.g., Hamel, 2006; Mol and Birkinshaw, 2006; Bloom et al., 2019). However, they also make it, and its effect on firm performance, more difficult to measure (Damanpour, 2014; Azar and Ciabuschi, 2017).

Following prior studies (e.g., Mol and Birkinshaw, 2009; Vaccaro et al., 2012), we use the dominant rational perspective on management innovation. According to this perspective, key individuals come up with novel solutions to organizational issues with the aim of increasing firm performance (Birkinshaw et al., 2008; Volberda et al., 2014). This rational perspective is in line with the resource-based view in that management innovation creates a more fruitful organizational context in which new and existing technological knowledge can be structured, bundled, and leveraged across the various parts and systems of a firm (Damanpour et al., 2009; Hervas-Oliver et al., 2018). This process of bundling and leveraging is needed for knowledge to be translated into a competitive advantage. This is a key managerial task (Van den Bosch et al., 1999; Sirmon et al., 2011), which requires intensive use of new management practices, processes, structures and techniques and has to be done in a synchronized way for them to work effectively (e.g., Whittington et al., 1999; Bloom et al., 2010). For instance, for new technological knowledge to be integrated and used more effectively, a set of new human resource management practices such as incentive pay plans, job flexibility and team-based work structures may be required (Bloom et al., 2010).

In the next section, we provide arguments on how management innovation influences the positive relationship between low levels of R&D and product innovation. We then discuss how management innovation influences this relationship when there are high levels of R&D.

2.3.1. *Low levels of R&D and product innovation: the moderating role of management innovation*

Firms with low levels of R&D but high levels of management innovation do not benefit from the complementary effects of these two types of activity, because R&D does not reach the 'threshold value' (Damanpour et al., 1989, p. 592) needed for this to occur (Damanpour et al., 2009; Damanpour and Aravind, 2012). These firms initially create an organizational context in which the focus is on using existing knowledge more effectively and on streamlining existing operational processes (Daft, 1982; Damanpour et al., 1989; Benner and Tushman, 2002). Under these conditions, R&D initially tends to be directed more at coming up quickly with products that will achieve high levels of commercial success (Artz et al., 2010). Resources such as time and effort are diverted away from activities such as product and business development that would allow a firm to benefit from R&D (Anzola-Román et al., 2018), thereby reducing R&D effectiveness (Benner and Tushman, 2002, 2003). When R&D investment is increased, the additional funds then tend to be directed toward basic research (Artz et al., 2010). The generation of new technological knowledge is then likely to take place at the periphery of the firm and largely in isolation from its existing core knowledge and operational processes (Orton and Weick, 1990; Benner and Tushman, 2003; Nunes and Breene, 2011).

Such a dominant focus on using existing knowledge efficiently and streamlining existing operational processes increases internal alignment. However, it reduces the dissemination and utilization of new knowledge from outside the firm's existing knowledge domains (Prajogo and Sohal, 2001; Jansen et al., 2009). Firms develop an increased 'collective blindness' (Nahapiet and Ghoshal, 1998, p. 245) with regard to new external knowledge, or they hide issues associated with that knowledge in order to maintain the status quo (Argyris and Schön, 1978; Katila and Ahuja, 2002). As a result, firms with low levels of R&D and high levels of management innovation initially have a greater tendency to overlook or ignore new technological knowledge that may lead to product innovation. They also find it more difficult to integrate and utilize that new knowledge (e.g., Prajogo and Sohal, 2001; Benner and Tushman, 2002; Zhou and Wu, 2010). Initially, this weakens their R&D effectiveness compared to firms with low levels of management innovation. Furthermore, it takes time before basic research pays off in terms of product innovation, because they start to invest more in R&D and the chances of failure are relatively high (e.g., Benner and Tushman, 2002; Jansen et al., 2006). This may initially cause a decline in product innovation for these firms (Artz et al., 2010). Accordingly, we expect that management innovation will initially weaken the positive relationship between low levels of R&D and product innovation.

2.3.2. *High levels of R&D and product innovation: the moderating role of management innovation*

Only when high levels of R&D are combined with high levels of management innovation can a firm exploit the complementary effects between them (Milgrom and Roberts, 1995; Damanpour et al., 2009; Damanpour and Aravind, 2012).

Management practices, processes, structures and techniques (management innovation) that are used more intensively – and are combined with adequate levels of R&D – help to create a more appropriate organizational environment in which to integrate and use new technological knowledge acquired through R&D (e.g., Damanpour et al., 1989, 2009; Whittington et al., 1999; Bloom et al., 2010; Azar and Ciabuschi, 2017). These conditions help to encourage internal diffusion and understanding of that new knowledge (Damanpour et al., 1989, 2009; Atuahene-Gima and Evangelista, 2000) and to create an organizational context that is more conducive to developing and introducing product innovation (Teece, 2010; Khanagha, Volberda and Oshri, 2014; Magnier-Watanabe and Benton, 2017).

In addition, high levels of management innovation enable managers to overcome managerial and organizational barriers that exist within and between various parts of the firm and that can hamper the process of transforming knowledge from R&D into product innovation (e.g., Siggelkow, 2001; Černe, Jaklič and Škerlavaj, 2013; Azar and Ciabuschi, 2017). For example, transforming high levels of new technological knowledge into product innovation requires the adjustment and alignment of many complementary areas of knowledge and capabilities, such as marketing and production (e.g., Nerkar and Roberts, 2004; Taylor and Helfat, 2009). Management innovation supports that transformation by creating a more coherent and self-reinforcing social system within the firm, which then allows new technological knowledge to be integrated and used more effectively (Wischnevsky and Damanpour, 2006; Bloom et al., 2010; Hervas-Oliver et al., 2018). Managers who engage in management innovation are also known to serve as innovation role models for their employees (De Jong and Den Hartog, 2007; Černe et al., 2013). This then reduces the behavioral barriers in terms of translating high levels of R&D into successful product innovation. Hence, we expect that management innovation will offset the negative relationship between high levels of R&D and product innovation.

Accordingly, we posit that, in the curvilinear relationship we expect to see between R&D and product innovation, management innovation will weaken both the left side of the curve (low levels of R&D) and the right side (high levels of R&D). This would indicate that this curvilinear relationship (H1) will apply especially to firms with low levels of management innovation. For firms with high levels of management innovation, we posit that the curvilinear relationship will initially be less positive but will subsequently become more positive. For these firms, we would therefore expect this relationship to follow a J-shaped curve (Whittington et al., 1999; Massini and Pettigrew, 2003). The impact on product innovation of complementary effects between high levels of both R&D and management innovation enables those firms to outperform others that conduct low levels of either of these two activities, as indicated by the upper right part of this curve. From these arguments, we expect that:

> H2: *The relationship between R&D and product innovation changes from a curvilinear one in firms with low levels of management innovation to a J-shaped relationship in firms with high levels of management innovation.*

3. Research methods

3.1. Data and sample

We randomly selected a sample of 10,000 companies from a commercial database containing information on companies registered with the Dutch Chamber of Commerce. The sample covered a broad range of industries and was restricted to firms with at least 25 employees. A member of the senior management team of those companies was invited to participate in the survey.

After several reminders, we ended up with 901 observations, 171 of which were removed because their score of zero on R&D investment suggested that hardly any new technological knowledge was being derived from R&D (Nooteboom, 1991). Consequently, we used 730 observations for the analysis. The companies are from a broad range of industries, including manufacturing (29% of observations), wholesale and retail (22%), real estate and professional services (17%), construction (11%), and transport and storage (6%). The average company is 31 years old and has 155 employees. Of the firms in our sample, a substantial proportion are small (72%), and a further 21% is medium-sized.

We conducted several tests to assess non-response bias. There were no significant differences ($P > .10$) between early and late respondents based on an independent sample T-test for our main constructs. Additionally, we examined whether the values for R&D investment for the participating organizations differed from those shown for Dutch companies in the commercial database. The Dutch companies that invest in R&D had an average value of 4.23 (standard deviation: 4.87). This is not significantly different from the average value on R&D investments of our responding firms ($P > .05$). These findings provide no indications of non-response bias in this survey.

We conducted several steps to assess common method bias. By assuring respondents of confidentiality and asking every manager to return the questionnaire to the research team, we reduced the common-method bias that can arise when respondents give their answers on the basis of social desirability, for example (Vaccaro et al., 2012). To further reduce the chances of common-method bias, we compared the scores from the perceptual scales with archival data wherever possible. A Harman's single-factor test with our full model (independent, dependent and moderating variables) indicated that all the items loaded on a single factor explained less than half of the variance (31%), indicating that common-method bias was not a serious problem in this study (Podsakoff and Organ, 1986).

To avoid single-response bias, a second member of the senior management team was also asked to complete the survey; around 8% of first respondents also had a second respondent. The inter-rater agreement scores (r_{wg}), based on intra-class correlation for the measures of management innovation and product innovation, indicate that there is 'moderate' to 'substantial' agreement between the first and second respondents, with the values being .49 ($P < .01$) and .76 ($P < .001$) respectively, according to the scale devised by Landis and Koch (1977). Pearson correlation coefficients indicate a strong consistency between the scores of the first and second respondents on management innovation ($r_{1,2} = .33$, $P < .001$) and on product innovation ($r_{1,2} = .61$, $P < .001$) (Jones et al., 1983).

3.2. Measurement of variables

Existing scales from the literature were used to measure our main constructs. All the main constructs were measured using a seven-point Likert scale, with the exception of R&D investment. More details of the items can be found in the appendix. Product innovation ($\alpha = .84$) was operationalized using the measure devised by Jansen et al. (2006). For example, one item is: 'We commercialize products and services that are completely new to our organization'. In line with Jansen et al. (2009), we also measured the correlation between the respondents' score on the measure of product innovation and the percentage of sales over the past three years that could be attributed to products and services which were completely new to the organization. This significant correlation ($r = .30$, $P < .001$) suggested that there was additional support for the reliability of our measure for product innovation.

R&D investment as a percentage of sales is one of the most common measures for R&D (e.g., Coombs and Bierly, 2006; Cruz-Cázares et al., 2013). Accordingly, in line with previous research (e.g., DeCarolis and Deeds, 1999; Berchicci, 2013), we used this to measure R&D over the past three years. As in prior research (e.g., Lee and Wu, 2016; Bravo and Reguera-Alvarado, 2017; Haans, 2019) assessing curvilinear relationships, we also included the squared term of the construct in the analyses.

The scale used to measure management innovation ($\alpha = .85$) is adapted from Vaccaro et al. (2012). This scale is based on the definition provided by Birkinshaw et al. (2008). An example of an item is: 'Rules and procedures within our organization are regularly renewed'. The first two items on this scale relate to management practices, the next two to management processes, and the final two to structure (Vaccaro et al., 2012). An advantage of this scale is that it is not confined to a specific new management practice (Vaccaro et al., 2012).

Various firm-level and environmental characteristics were incorporated as control variables due to their known impact on product innovation. Environmental dynamism ($\alpha = .78$) influences the need for product innovation (e.g., Crossan and Apaydin, 2010), and is included by applying the construct of Jansen et al. (2006). Since firm performance influences the need for a firm to innovate, its willingness to do so, and the resources available (Laursen, 2012), a proxy for it ($\alpha = .83$) was used as a control variable (cf. Wiklund and Shepherd, 2005). Investment in R&D may be strongly related to firm size; larger firms have greater economies of scale in R&D (Ahuja, Lampert and Tandon, 2008) and may also have high levels of management innovation (Mol and Birkinshaw, 2009). Firm size was measured by the logarithm of full-time employees. Older organizations might have accumulated more experience and have developed inertia, which can affect innovation. However, they may have more resources to use for innovation (Jansen et al., 2006). Firm age was therefore included, measured by the number of years since the firm was founded. CEO tenure influences a firm's propensity to change and experiment (Wu, Levitas and Priem, 1996), and therefore it was also included. The size of a top management team can influence its heterogeneity (Siegel and Hambrick, 2005), so we also included this, measuring it by the number of managers in the senior management team. Differentiating between manufacturing and service-oriented firms allows us to take into account differences between industries in the demand and opportunities for innovation (Damanpour et al., 2009; Walker et al., 2015).

We included both industrial and service firms in the analyses, with the first being used as a dummy variable. Industrial firms are those that are active in, for instance, the chemical, energy, manufacturing and mining industries. Service firms are typically active in sectors such as financial services, real estate and professional services, and wholesale and retail.

3.3. Assessment of latent variables

Reliability analyses based on Cronbach's α exceeded by at least .84 the threshold of .7 (Field, 2009). We assessed the construct validity of our main latent variables (management innovation and product innovation) through exploratory factor analysis using a principal component analysis with varimax rotation. Two factors were identified with eigenvalues over Kaiser's criterion of 1, with each item loading clearly on to its intended factor. Items had communalities larger than 0.3; dominant loadings were at least 0.59, which is above the threshold value of 0.5, and cross-loadings were not more 0.21, which is within the acceptable limit of 0.3 (Briggs and Cheek, 1988). Using AMOS 21, we applied confirmatory factor analyses (CFA) based on maximum likelihood procedures in order to validate the main measures from our exploratory factor analysis (Hair et al., 2006). The measures indicated that our data have an overall acceptable fit with our model (χ^2/df = 4.73 < 5; goodness-of-fit index (GFI) = 0.94 ≥ 0.90; comparative fit index (CFI) = 0.93 ≥ 0.90; root-mean-square error of approximation (RMSEA) = 0.07 < 0.08) (Bentler and Bonett, 1980). All factor loadings were above the 0.40 level recommended by Ford, MacCallum and Tait (1986), and their loadings on the proposed indicators were significant ($P < .01$), thereby indicating the convergent validity of our measures (Anderson and Gerbing, 1988). A single-factor CFA model provided a less acceptable fit to our model (χ^2/df = 25.2; GFI = 0.65; CFI = 0.56; RMSEA = 0.19), indicating discriminant validity (Bagozzi and Phillips, 1982). Overall, our findings from exploratory and confirmatory factor analysis indicate the convergent and discriminant validity of our main latent measures.

4. Analyses and results

Table 1 presents the means and standard deviations of the constructs and the correlations between them. During the sampling period, R&D investment, management innovation, and product innovation were statistically significant correlated. It is interesting

Table 1. Means, standard deviations and correlations

	Mean	Standard deviation	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Product innovation	4.06	1.16	1.00									
(2) R&D	4.22	4.88	0.26***	1.00								
(3) Management innovation	3.45	1.14	0.36***	0.07*	1.00							
(4) Environmental dynamism	4.28	1.20	0.38***	0.09*	0.19***	1.00						
(5) Firm performance	4.74	0.95	0.23***	0.11**	0.10**	0.03	1.00					
(6) Firm size	1.76	0.51	−0.01	−0.09*	0.08*	−0.06†	0.02	1.00				
(7) Firm age	30.90	27.93	−0.06†	−0.06	−0.08*	−0.11**	−0.06†	0.16***	1.00			
(8) CEO tenure	13.32	10.44	0.04	−0.04	−0.05	0.04	0.01	−0.04	0.13***	1.00		
(9) Size of top management team	5.86	5.20	0.04	0.03	0.13***	−0.03	0.07*	0.20***	0.06†	0.05	1.00	
(10) Industrial firms	0.41	0.49	−0.05	−0.11**	−0.11**	−0.08*	0.01	0.07*	0.25***	0.09**	−0.02	1.00

Notes: In this table, a firm's scores on R&D and management innovation are not yet mean-centered.
***$P < .001$, **$P < .01$, *$P < .05$, $^{\dagger}P < .10$.

to note that in particular the correlation between management innovation and product innovation is rather strong. To assess potential multicollinearity problems, we calculated the variance inflation factor (VIF). The highest VIF (3.43) is well below the rule of thumb of 10 (Neter, Wasserman and Kutner, 1990), suggesting no such problems.

Table 2 presents several regression analyses based on ordinary least squared analyses. Model I presents the effect of our control variables on product innovation. Model II is similar to Model I, but with the effect of R&D added. Model III adds the moderating effect of management innovation to Model II. In this third model, we followed procedures used by Haans (2019) by including the interaction term of management innovation with both R&D and R&D squared in order to assess the second hypothesis.

Consistent with several existing studies (e.g., Acs and Audretsch, 1988; Graves and Langowitz, 1993), we find that R&D has a decreasingly positive relationship with product innovation. Analyses of our data thus support H1: R&D has a positive relationship ($P < .001$) with product innovation, but for high levels of R&D, this relationship is negative ($P < .05$). Figure 1a depicts the effect of R&D on product innovation. As shown in this figure, the slope of the effect of R&D on product innovation decreases as the level of R&D rises.

Regarding the moderating role of management innovation on the relationship between R&D and product innovation, our findings also support H2: management innovation flattens the positive effect of low levels of R&D on product innovation ($P < .001$) and offsets the negative effect of high levels of R&D on product innovation ($P < .01$). As

Table 2. Results of hierarchical regression analyses: effect of R&D on product innovation

Model	I	II	III
Independent variable			
R&D		0.28***	0.27***
		(0.01)	(0.01)
R&D squared		−0.12*	−0.13*
		(0.00)	(0.00)
Management innovation		0.27***	0.22***
		(0.03)	(0.04)
Moderating effects			
R&D × Management innovation			−0.18***
			(0.01)
R&D squared × Management innovation			0.16**
			(0.00)
Control variables			
Environmental dynamism	0.37***	0.30***	0.30***
	(0.03)	(0.03)	(0.03)
Firm performance	0.22***	0.18***	0.18***
	(0.04)	(0.04)	(0.04)
Firm size	−0.01	−0.01	−0.02
	(0.08)	(0.07)	(0.07)
Firm age	−0.01	0.00	0.00
	(0.00)	(0.00)	(0.00)
CEO tenure	0.02	0.03	0.03
	(0.00)	(0.00)	(0.00)
Size of top management team	0.04	−0.02	−0.02
	(0.01)	(0.01)	(0.01)
Industrial firms	−0.02	0.04	0.04
	(0.08)	(0.08)	(0.08)
F	27.05***	29.84***	26.19***
R^2	0.19	0.29	0.31
Adjusted R^2	0.18	0.28	0.29

Notes: Standardized coefficients are described. Values between parentheses are standard errors.
$^{***}P < .001$, $^{**}P < .01$, $^{*}P < .05$, $^{\dagger}P < .10$.

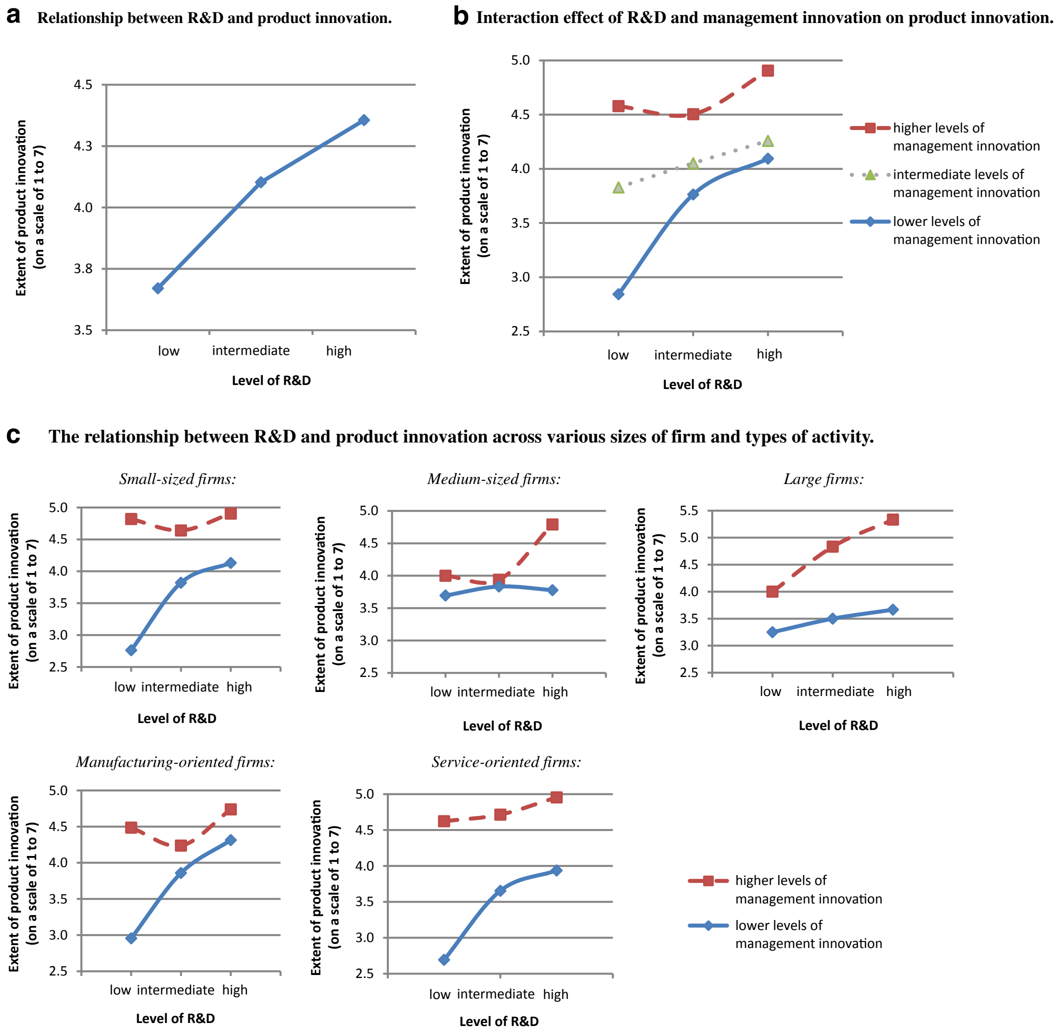

Figure 1. (a) Relationship between R&D and product innovation; (b) interaction effect of R&D and management innovation on product innovation; (c) the relationship between R&D and product innovation across various sizes of firm and types of activity. [Colour figure can be viewed at wileyonlinelibrary.com]

shown in Figure 1b, analyses of our data indicate that R&D has a decreasingly positive relationship with product innovation in firms with low levels of management innovation. However, this relationship is more J-shaped for firms with high levels of management innovation. Together, these findings indicate that management innovation is a key contextual variable that can explain variations in R&D effectiveness.

Interestingly, Figure 1b also shows that the average scores on product innovation are consistently high for firms with high levels of management innovation compared to those with low levels, regardless of the level of R&D. As shown in Model III of Table 2, management innovation also has a direct positive effect on product innovation ($P < .001$).

Additional analysis of our data reveals that our findings are quite consistent across small, medium-sized, and large firms as well as between manufacturing and service firms (see Figure 1c). In most cases, the relationship between R&D and product innovation is decreasingly positive if firms have a low level of management innovation. The curve of the relationship between R&D and product innovation is relatively flat in medium-sized and large firms with low levels of management innovation.

In small and medium-sized firms with a high level of management innovation, the relationship between R&D and product innovation followed a J-shaped curve as we had expected, and this was consistent across firms engaged in various types of activity. However, this is not the case for large firms. There the relationship between R&D and product innovation follows a consistent upward slope, even with low levels of R&D (as shown in

Figure 1c). However, even with this alternative shape, large firms with high levels of management innovation also score high on product innovation, regardless of their level of R&D. Large firms with high levels of both R&D and management innovation even outperform small and medium-sized firms with comparable levels of both types of activity (see Figure 1c).

5. Discussion and conclusion

R&D is an important source of competitive advantage, but there are relatively few theoretical insights and little systematic empirical evidence to indicate whether management innovation explains variations in a firm's R&D effectiveness. With this study, we advance understanding of how management innovation moderates the relationship between R&D and product innovation in various ways.

First, we argue that management innovation, as a moderator, does indeed explain variations in a firm's effectiveness at converting R&D into product innovation. It may reduce R&D effectiveness when the level of R&D is low or may increase it when the level is high. This contextual influence is characterized by a curvilinear relationship between R&D and product innovation that becomes more of a J-shaped relationship as the level of management innovation increases. The upper right part of this curve indicates the impact on product innovation of having complementary effects of high levels of both R&D and management innovation.

This theoretical contribution adds new insights to prior research on how R&D affects firm outcomes (e.g., Acs and Audretsch, 1988; DeCarolis and Deeds, 1999; Lin, Lee and Hung, 2006) and helps to explain its mixed effects (e.g., Artz et al., 2010; Erden et al., 2014). It highlights the importance of management innovation as a contextual variable when explaining variations in firms' R&D effectiveness. We have provided theoretical arguments on how R&D effectiveness varies in firms with differing levels of both R&D and management innovation. For example, our theoretical arguments indicate that, all other things being equal, a decreasingly positive relationship will be found in firms with low levels of management innovation (cf. Acs and Audretsch, 1988; Graves and Langowitz, 1993). Unless firms engage in sufficient levels of management innovation, their product innovation will not be able to benefit from the complementary effects between this form of innovation and high levels of R&D. Examining the performance effect of R&D without taking into account management innovation therefore only provides a limited explanation of the variations in this relationship.

In addition, we add to prior studies on the impact on firm performance of complementary effects between technological innovation and management innovation (e.g., Damanpour et al., 2009; Hervas-Oliver and Sempere-Ripoll, 2015; Azar and Ciabuschi, 2017) and between different management practices (e.g., Whittington et al., 1999; Massini and Pettigrew, 2003; Whittington and Pettigrew, 2003). It has been argued that firm performance is, in theory, a less accurate indicator of R&D output than product innovation (e.g., Coombs and Bierly, 2006; Cruz-Cázares et al., 2013; Walker et al., 2015). We provide arguments as to how R&D – a key indicator of (technological) innovation – and management innovation jointly drive product innovation. Firms that have high levels of both R&D and management innovation are able to outperform firms with lower levels of each because these activities have complementary effects on product innovation.

These arguments highlight the importance of taking into account variations in the level of technological innovation when examining how the joint introduction of technological and management innovation influences firm outcomes. Overall, management innovation seems to increase the effectiveness of technological innovation by altering the extent to which newly generated technological knowledge is converted into product innovation. With these arguments, we respond to a previous suggestion for more conceptual development of 'how a balance between MIs [management innovations] and TIs [technological innovations] could affect organizational conduct and outcome' (Walker et al., 2015, p. 418).

Furthermore, we make an empirical contribution by examining the nature of the relationship between management innovation and R&D effectiveness. Using more finely graduated scales rather than dichotomous scales to measure the intensity of R&D and management innovation has enabled us to look beyond linear relationships. It has allowed us to estimate how various levels of both these types of activity affect product innovation (see Figure 1b). In so doing, we are responding to the call for researchers to look at nonlinear effects of R&D and management innovation (Erden et al., 2014; Walker et al., 2015).

In particular, our empirical findings provide a new perspective on precisely what effect R&D and management innovation have on product innovation when used in combination. Until now, it has remained somewhat unclear whether the effects of technological innovation and management innovation are actually complementary, substitutable or independent (Anzola-Román et al., 2018; Romano, 2019). Our empirical findings show that the relationship between R&D and product innovation varies with differing levels of both R&D and management innovation (see Figure 1b). Firms that focus solely on increasing either management innovation or R&D – especially small and medium-sized firms (SMEs) – utilize new technological knowledge to a lesser extent. These findings imply that firms which pursue more product innovation by investing mainly in more R&D will achieve suboptimal outcomes in terms of product innovation. If firms increase their levels of both R&D *and* management innovation, at a certain point the complementary effects between the two activities mean that product innovation will improve. In the initial stages, however, they may experience a temporary reduction in product innovation.

This temporary decline in product innovation seems to apply less to large firms that start investing more in R&D and management innovation (see Figure 1c). This may be because they have certain advantages over smaller firms. For instance, they have more opportunities to develop and introduce product innovations largely in isolation from their mainstream activities (e.g., Damanpour, 1996; Benner and Tushman, 2003). Large firms can also draw on their more extensive asset base, including their established distribution channels, to realize product innovation (e.g., Markides and Oyon, 2010; Voss and Voss, 2013). They may be more able to introduce management innovation and have a greater need to do so (Mol and Birkinshaw, 2009). With the right management practices, processes, structures and techniques in place, large firms may be better able to convert new technological knowledge derived from low levels of R&D into product innovation. Future research should examine this interesting phenomenon in more detail. Notably, just like SMEs, in our study large firms with high levels of both R&D and management innovation score higher on product innovation than those with low levels of either of these activities.

Interestingly, our findings also reveal that, regardless of the level of R&D, firms with high levels of management innovation typically score better on product innovation than firms with low levels (see Figure 1b). These findings provide empirical support for prior research (e.g., Volberda and Van den Bosch, 2005; Mol and Birkinshaw, 2006; Teece, 2010; Sirmon et al., 2011) in which it has been argued that the role of management in transforming technological knowledge into successful firm outcomes is generally more important for competitive advantage than technological knowledge itself. As pointed out by Hansen et al. (2004, p. 1280), for instance, 'what a firm *does* with its resources is at least as important as *which* resources it possesses'. While we do not question the significance of R&D for organizational survival, our findings provide empirical evidence that underlines the vital role of managers, and particularly management innovation, in increasing R&D effectiveness.

Regarding the managerial implications of our study, our findings indicate that management innovation can be both detrimental and beneficial in terms of R&D's effect on product innovation. On the one hand, our findings indicate that when firms, especially SMEs, with high levels of management innovation start to invest in R&D, they paradoxically experience an initial decline in product innovation compared to firms with low levels of management innovation. They then have a greater tendency to overlook or ignore new technological knowledge derived from R&D and also find it more difficult to integrate and utilize that new knowledge. On the other hand, high levels of management innovation are needed to boost R&D effectiveness, since when this is combined with similarly high levels of R&D, firms are able to integrate and utilize new technological knowledge more effectively. This paper thus shows that a one-sided focus on either R&D or management innovation is not sufficient to unlock the potential for product innovation. Many firms have an officer responsible for R&D or technological innovation, for example, a Chief Technology Officer. Given the importance of management innovation in enhancing product innovation, arguably firms ought to show the same level of commitment to this non-technological innovation. This might be done, for example, by appointing an officer with direct responsibility for management innovation.

In spite of these contributions, our study also has several limitations that indicate useful directions for future research. First, we have focused on product innovation by defining this as the number of radical new products and services introduced over a certain timespan. Various other studies have focused on the degree of newness involved (e.g., Benner and Tushman, 2002; Danneels, 2002) or highlighted several other types of product innovation such as more incremental ones (Henderson and Clark, 1990; Levinthal and March, 1993). Our research model could be extended in future research by including both of those approaches. Second, new technological knowledge from R&D

can also be applied outside the boundaries of the firm, through open innovation; this might be done through licensing or by forming alliances (e.g., Enkel, Gassmann and Chesbrough, 2009). R&D has also been found to enhance absorptive capacity, namely the firm's ability to assimilate knowledge developed by others (Cohen and Levinthal, 1990; Griffith, Redding and Van Reenen, 2003). We encourage future research to extend our model by including the role of absorptive capacity and open innovation. Third, we have focused on management innovation as a generic concept (cf. Birkinshaw et al., 2008), and have not differentiated between specific types of new management practices such as self-organization or incentive pay plans (Volberda et al., 2013). We encourage future research to examine whether our findings might vary according to the type of management innovation used. Fourth, we have not examined the role of time in our model. Complementary effects may be revealed over time (Damanpour et al., 2009), and organizational change can be divided into episodic change and continuous change (e.g., Weick and Quinn, 1999). Future research should examine, using longitudinal case studies, how management innovation may increase R&D effectiveness over time.

Overall, we help to build a richer understanding of how management innovation as a moderator influences a firm's effectiveness at transforming R&D into product innovation. Innovation effectiveness is expected to become a key indicator of leading firms (Cruz-Cázares et al., 2013).

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Note

1. Social innovation has been defined in two main ways (e.g., Pol and Ville, 2009). It has been referred to as the introduction of a certain number of new elements within a firm's social system (e.g., Gardner, Acharya and Yach, 2007; Volberda and Van den Bosch, 2005). According to this perspective, examples of social innovation include the introduction of self-organizing teams or new performance incentives. According to the second perspective, social innovation is about finding a new solution to address a societal problem where society as a whole is the main beneficiary of the added value of that new solution, rather than private individuals (e.g., Phills, Deiglmeier and Miller, 2008; Pol and Ville, 2009). In line with this second perspective, an example of a social innovation is the introduction of a new initiative to address inequality within society. In this paper, we focus on the first perspective on social innovation.

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Appendix A. Measures and items at firm level

Product innovation (adapted from Jansen et al., 2006).

- Our organization accepts demands that go beyond existing products and services.
- We invent new products and services.
- We experiment with new products and services in our local market.
- We commercialize products and services that are completely new to our organization.
- We frequently utilize new opportunities in new markets.
- Our organization regularly uses new distribution channels.

Management innovation (adapted from Vaccaro et al., 2012).

- Rules and procedures within our organization are regularly renewed.
- We regularly make changes to our employees' tasks and functions.
- Our organization regularly implements new management systems.
- The policy with regard to compensation has been changed in the last three years.
- The intra- and inter-departmental communication structure within our organization is regularly restructured.
- We continuously alter certain elements of the organizational structure.

Environmental dynamism (adapted from Jansen et al., 2006).

- Environmental changes in our local market are intense.
- Our clients regularly ask for new products and services.
- In our local market, changes are taking place continuously.
- In a year, nothing has changed in our market (reversed item).
- In our market, the volumes of products and services to be delivered change fast and often.

All items are measured on a seven-item scale ranging from 'strongly disagree' (1) to 'strongly agree' (7).

Firm performance (adapted from Wiklund and Shephard, 2005).

Respondents were asked to estimate their performance over the last year compared to competitors. The answers range from 'much worse than our competitors' (1) to 'much better than our competitors' (7). The items used for comparison are:

- Revenue
- Profit
- Return on assets
- Growth of market share

