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ONE SIZE (DOES NOT) FIT ALL: EVIDENCE OF SIMILARITIES AND DIFFERENCES BETWEEN PRODUCT INNOVATION MANAGEMENT IN HIGH- AND LOW-TECH MANUFACTURING FIRMS

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Most literature on product innovation management (PIM) has developed through a small number of high-tech manufacturer studies. It is assumed that, for other types of firms, 'one size fits all'. This research addresses this issue by investigating PIM in both high- and low-tech firms. Building on Cormican and O'Sullivan's (2004) *Best Practice Model* (*BPM*) this paper analyzes PIM of 112 high-tech in comparison to 184 low-tech manufacturing firms in the Netherlands. The empirical results show significant sector-level differences in the impact of the five constructs and, in some cases, insignificant and even opposite effects. Our findings show that one size does not fit all, and blindly following the theory can not only have a suboptimal effect but may even have a negative effect. Furthermore, there are some similarities in high- and low-tech PIM, for example *Communication and Collaboration* is the only construct that is positive and significant in all cases. The implications of these results in relation to high- and low-tech manufacturing firms are discussed.

Keywords: Innovation; product innovation management; product innovation performance; product innovation performance in high- and low-tech manufacturing firms.

Introduction

The literature suggests that product innovation management (PIM) is vital to firm performance (Artz *et al.*, 2010), and testifies to the importance of specific factors such as culture (Denham and Kaberon, 2012; Jassawalla and Sashittal, 2002), leadership (Barczak *et al.*, 2009; Burgelman *et al.*, 2004; Denham and Kaberon, 2012), management support (Barczak *et al.*, 2009; March-Chordà *et al.*, 2002; Markham and Lee, 2013), and customer involvement (Lau *et al.*, 2010) in explaining the effectiveness of the firms' PIM process. While the research literature has addressed low-tech firms to some degree, as reflected for example in the meta-analytical study of Rubera and Kircha (2012) and a comparative study by Reboud *et al.* (2014), these studies remain limited. Also, government policy (Lundvall, 2007) tends to concentrate on high-tech industries, frequently referred to as the Silicon Valley Business Model (OECD, 2010). There are very few dedicated low-tech innovation studies, and less on the factors that predict effective PIM in the low-tech sector (Freeman and Soete, 1997; Hidalgo and Albors, 2008). Much of the research on PIM comes from the studies of high-tech industries, and it has been assumed, implicitly, that "one size fits all". Generally, the low-tech sector has been largely "forgotten" by innovation scholars (Hirsch-Kreinsen, 2008), and managers of low-tech firms have been abandoned to discover what works and what does not work, hence, there is a major need for comparative research investigating high- and low-tech PIM. Most significantly, according to Eurostat, low-tech industries represent more than twice the share of total manufacturing than high-tech firms represent, while employing more than five times as many people. Low-tech firms are a major part of society and deliver significant economic benefits that must be recognised and developed in ways that can generate greater value.

The OECD classifies firms with more than 5% of annual turnover invested into R&D as "high-tech", and those with less than 5% of annual turnover invested into R&D as "low to mid-tech" (Hirsch-Kreinsen *et al.*, 2008). There are fundamental differences between both categories of firms (Covin *et al.*, 1990; Reboud *et al.*, 2014). These differences are most pertinent to the number and type of innovations generated and the way firms manage the process of commercialisation (Mazzarol and Reboud, 2011). According to Hirsch-Kreinsen (2008), the way low-tech firms innovate is quite different from the stylized way high-tech firms innovate. High- and low-tech sectors have a specific technological and knowledge base, learning pattern, network and culture that define sector-specific modes of innovation. Due to the central role of knowledge intensity and novelty in the high-tech sectors, high-tech innovation is usually characterised as turbulent, unpredictable, and uncertain (Moriarty and Kosnik, 1989). In high-tech, science-based industries, for example, the pharmaceutical industry, innovation is R&D-based one (Hatzichronoglou, 1997; Hirsch-Kreinsen, 2008), and is highly R&D intensive (Reboud *et al.*, 2014). Hence, this is very different from the low R&D-based innovation that occurs in low-tech industries (Reboud *et al.*, 2014) such as wood and paper, where innovation is based on accumulated practical experience and specialisation (Malerba, 2004; Nelson and Winter, 1977). Furthermore, high-tech manufacturers benefit more from R&D investment that is directed towards product development, while low-tech firms benefit from investment in product development process innovations (Reboud *et al.*, 2014). Low-tech firms frequently operate in markets where consumers perceive their product to be identical, or very similar, to that of their competitors (Arping and Lóránth, 2006; Boyaci and Ray, 2006; Hwang *et al.*, 2008; Damanpour, 2010; Hsu, 2009). Whereas high-tech manufacturers are frequently protected by patents, trademarks, and have the ability to offer strongly differentiated products.

This study brings these distinct streams of research of high- and low-tech PIM on product innovation performance into sharper focus through a quantitative analysis. In this study, we investigate the similarities and differences of PIM on product innovation performance in high- and low-tech manufacturing firms, which may help firms engender more effective product innovation performance in unique and complimentary ways. This research builds upon the notion that "one size does not fit all" and there is a fundamental need for the two sectors to have greater distinctiveness in order to achieve the highest level of product innovation performance for both. To address this, we strive to answer two important research questions: What are the key similarities and differences between PIM in high- and low-tech manufacturing firms? and what forms of PIM are best associated with higher innovation performance in high- and low-tech manufacturing firms? For this purpose, we build on Cormican and O'Sullivan's (2004) *Best Practice Model* (BPM) to survey 296 Dutch firms, of which 112 are classified as high-tech and 184 as low-tech manufacturing firms. This study extends the existing conceptualisations and research by empirically testing for similarities and differences in the importance for innovation performance of the five constructs of the Cormican and O'Sullivan (2004) model in high- and low-tech manufacturing firms. In doing so, this research contributes to the richness of PIM by examining the potential influential factors in high- and low-tech manufacturing firms to achieve higher levels of product innovation performance.

This study offers several meaningful contributions to the innovation and broader management literature: (1) This research is one of the few studies to fill the gap in our understanding by investigating the similarities and differences of PIM in high- and low-tech manufacturing firms and enhances our knowledge of product innovation performance among those firms. (2) This research opens the door to a new perspective of thinking about PIM in high- and low-tech manufacturing firms that has received scant attention over the last decade. (3) Finally, this research underscores the importance of key factors influencing PIM if the firm is to reap the potential benefits associated with achieving higher levels of product innovation performance.

In the following section, we explain the theoretical framework of this research and elaborate on our research model and derive specific testable hypotheses from it. Next, the sample measures and analytical techniques of this research are discussed in the methods section. In the results section, we present our findings. Finally, we discuss the findings and conclude with limitations and directions for future research.

Theoretical Framework and BPM Research Model in High- and Low-Tech Firms

PIM is the creation and subsequent introduction of a good or service that is either new, or an improvement on previous goods or services (Amabile *et al.*, 1996). It is a process, which incorporates a number of technical, R&D, manufacturing, management and commercial activities (Alegre and Chiva, 2008). Product development is complex but of significant importance to organisational profit and survival (Markham and Lee, 2013). The importance of PIM for positive long-term organisation performance is widely recognised and has been extensively reported in the literature (Lemon and Sahota, 2004; Markham and Lee, 2013; Montalvo, 2006). Firms that experiment with highly innovative ideas contribute to new product success (McLean, 2005). However, it is recognised that innovation can take many forms, such as "developing new products and services, developing new methods of production, identifying new markets, identifying new sources of supply, and developing new organisational strategies" (Hisrich and Kearney, 2013, p. 50). While radical innovations are of significant importance, they are consistently found to generate more positive performance outcomes than incremental innovations do (Rubera and Kirca, 2012), most innovations make incremental improvements to existing products or services rather than risk of bringing something radically novel to the marketplace (Hisrich and Kearney, 2013). Low-tech firms can innovate but may be more likely to achieve incremental innovations rather than radical innovations (Raymond and St-Pierre, 2010), because radical innovations are generally infrequent in low-tech industries (Szymanski *et al.*, 2007). To effectively manage innovation, there is a need for more sophisticated processes and methods to gain market entry, understand customer needs, achieve technological advancement, utilise company capabilities, ensure appropriate distribution, and effective product management (Markham and Lee, 2013).

Much work has also been done in the past two decades, to answer the question of how the firm can effectively manage its product innovation process. An excellent and extensive literature point to firm-level factors, such as "culture" (Denham and Kaberon, 2012; Jassawalla and Sashittal, 2002), "customer and supplier involvement" (Lau *et al.*, 2010), "leadership" (Barczak *et al.*, 2009; Burgelman *et al.*, 2004; Denham and Kaberon, 2012) and "management support" (Barczak *et al.*, 2009; March-Chordà *et al.*, 2002) in explaining the effectiveness of the firms product innovation process, and a number of helpful models have emerged to help managers to enhance the effectiveness of their operations (Chiesa *et al.*, 1996; Tidd *et al.*, 2001; Tidd and Bessant, 2009). Research shows that low-tech product innovators differ from their high-tech counterparts in terms of structure, type of innovation, market orientation, equity finance and product management team experience (Covin and Prescott, 1990; Reboud *et al.*, 2014). Further differences highlight that the strategic planning processes of high-tech firms will differ from those of low-tech firms, and that there will also be a different emphasis placed on the drivers of strategic planning, organisational culture and leadership (Barczak *et al.*, 2009; Denham and Kaberon, 2012; Markham and Lee, 2013; O'Regan and Ghobadian, 2005; Reboud *et al.*, 2014). In this study, our objective is to test a theoretically driven comprehensive framework proposed by Cormican and O'Sullivan (2004) that provides an overview of company's strengths and weaknesses with regard to PIM, and suggests that PIM depends on five firm-level factors: (1) *Strategy and Leadership*, (2) *Culture and Climate*, (3) *Structure and Performance*, (4) *Planning and Selection*, (5) *Communication and Collaboration*. To provide theoretical guidance, we build on the Cormican and O'Sullivan (2004) model using the five proposed firm-level factors in light of how the business environments have changed, the competitive environment is even more globalised, innovation is a necessity for organisational survival and profit, and technological advancements and development is emerging at an unrelenting pace. It follows that PIM in high- and low-tech firms may incorporate significant differences based on the diverse environments in which they operate and the frequency which they engage in product innovation activities, thus resulting in different performance.

Strategy and leadership

In the Cormican and O'Sullivan (2004) model, "strategy" refers to product strategy, which describes the aims, objectives, and strategic areas of the product innovation effort. There is a much greater likelihood that higher performing firms will develop and articulate concise goals and objectives that are congruent with strategy (Barczak *et al.*, 2009). Therefore, the greater the level of congruence between the innovation and the strategy, the more likely the firm will succeed in developing a commercially viable product. A product strategy facilitates team effort, permits delegation, determines how resources should be allocated, and helps the selection of projects.

"Leadership", in the BPM, refers to the act of defining a product strategy, and of guiding the product innovation process (Cormican and O'Sullivan, 2004). A fundamental component of many firms' innovation strategy is management participation (Markham and Lee, 2013). Leaders are required to establish a working environment that stimulates creativity, to create an organisational atmosphere that serves as a guiding principle for more creative processes, and to develop and maintain a system that provides rewards to creative performances. Yet, Barczak *et al.* (2009) found that innovation support and leadership by senior management was an area of new product development that required improved management support. Senior managers in the highest performing firms support innovation significantly more than in other firms (Markham and Lee, 2013). Hence, the importance of the senior management in the implementation of an innovative strategy is a key contributor to product innovation performance. Leaders must ensure that the firm's vision is aligned with its strategy, and that the strategy is supported, communicated and disseminated throughout the organisation.

A significant literature documents the important role of "strategy and leadership" in understanding high-tech product innovation performance (Burgelman *et al.*, 2004; Chiesa *et al.*, 1996; Cooper and Edgett, 2010; Cooper and Kleinschmidt, 2007; Cormican and O'Sullivan, 2004; Englund and Graham, 1999; Goffin and Pfeiffer, 1999; Sánchez *et al.*, 2011). Studies have shown that firms that develop clear innovative strategies and share and foster corresponding goals can achieve high innovation performance (Ferreira *et al.*, 2015; Tidd and Bessant, 2009). Furthermore, Markham and Lee's (2013) study also found significant differences in management participation between higher and lower performing firms. However, little is known about the differences between the impact of "strategy and leadership" on the product innovation process in the low-tech sector

(O'Regan and Ghobadian, 2005). Therefore, in the context of low-tech product innovation, this leads us to suggest that strategy and leadership may play a less significant role in the low-tech sector than in the high-tech sector. Accordingly, one may find a stronger disposition toward strategy and leadership for greater innovation in high-tech industries than in low-tech industries. Thus, we propose the following hypothesis:

H1: *Innovative strategies and leadership are more positively associated with product innovation performance in high-tech industries than in low-tech industries.*

Culture and climate

In the BPM, "culture" refers to the organisational culture of the firm, which is "the underlying values, beliefs, and principles that serve as a foundation for an organisation's management system as well as the set of management practices and behaviours that exemplify and reinforce those basic principles" (Denison, 1990, p. 2). Culture forms the informal, behavioural component of an organisational context (Denison, 1996), complementing the formal structural component (e.g., processes and systems). An organisation's innovation culture has been recognised as fundamental to product development (de Brentani and Kleinschmidt, 2004). Hence, leaders must manage a culture that embraces successes, learns from failures and supports and facilitates innovation (Hisrich and Kearney, 2013). Culture is developed as an organisation learns to cope with the dual problems of direction and flexibility as well as external adaptation and internal integration (Schein, 1990). "Climate", in the BPM, refers to an organisational climate, which describes the firm's policies, practices, and rewards (Cormican and O'Sullivan, 2004). Culture and climate are interconnected concepts (Schneider *et al.*, 1996), because policies, practices and procedures (climate) change, when management values and beliefs (culture) change. Climate, however, is the more easily modified construct (Tidd and Bessant, 2009).

An extensive literature points to the importance of culture and climate in the high-tech sector. Maidique and Hayes (1984, p. 25), for example, argue that "one of the most important characteristics of a successful high-technology firm is an entrepreneurial culture". High-tech firms that are fast paced, freewheeling, high energy, and entrepreneurial, and characterised by openness, support, excellent communication, trust, knowledge sharing and learning together, and a sense of common responsibility (Arad *et al.*, 1997; Martins and Terblanche, 2003; Burgelman *et al.*, 2004; Chiesa *et al.*, 1996; Cooper and Kleinschmidt, 1995; Cormican and O'Sullivan, 2004). Wang and Rafiq (2014) suggest that while traditional firms have a top-down mentality, the culture in high-tech firms is built bottom-up, through individual involvement and participation. The result, they suggest, is an ambidextrous organisational culture, in which greater participation and involvement leads to product innovation outcomes (Wang and Rafiq, 2014).

Culture is associated with the level that firms utilise new technologies (Markham and Lee, 2013). Speculating about the low-tech sector, research shows that the level of technology deployed will impact on organisational culture resulting in differing levels of corporate performance (O'Regan and Ghobadian, 2005). Furthermore, it has been shown that in low-tech firms, short-term performance is the only significant correlation between low-tech culture style and performance (O'Regan and Ghobadian, 2005). An innovative culture fosters the creation and implementation of new ideas (Denham and Kaberon, 2012). Furthermore, it represents the degree that a firm has developed specific competencies that make it more productive in the utilisation of resources that facilitate innovation (McGrath *et al.*, 1996; Szymanski *et al.*, 2007). Hence, high-tech firms more frequently engage in innovation and have greater opportunities to enhance product innovation performance providing a greater scope for the development of an innovative culture and climate. Therefore, one would expect to find higher levels of innovation in the culture and climate of firms in high-tech industries. Accordingly, the following hypothesis is proposed:

H2: *An innovative culture and climate is more positively associated with product innovation performance in high-tech industries than in low-tech industries.*

Planning and selection

In the BPM, "planning and selection" refers to project planning and project selection. "Planning" describes the way in which the firm conducts research, and develops a sharp and clear definition of the product, before developing anything (Cooper and Kleinschmidt, 2007). Planning activities are commonly used by firms for determining a context within which choices are made, such as comparing alternatives and choosing a particular direction for business activities and for management control of activities (Scott, 2001). "Selection", by contrast, describes the way in which the firm chooses projects, which are linked to the overall strategy and goal of the organisation, to customers' needs (de Brentani, 2001; Rese and Baier, 2011), and to each other, in terms of creating cross-project synergies (Cooper, 1999).

An extensive literature suggests that "planning and selection" are key predictors of the high-tech firms product innovation performance (Cooper and Kleinschmidt, 2007; Cormican and O'Sullivan, 2004; de Brentani, 2001). Strategic planning is not only the top technology management problem of product development in high-tech firms, but it is also the cornerstone problem (Scott, 2001). Hence, Hadjimanolis (2000) suggests that planning and selection is the key factor that distinguishes innovative from less innovative firms. Radical innovations are usually more costly to develop in comparison to incremental innovations (Rubera and Kirca, 2012). However, radical innovations achieve advantage over incremental innovations that generally offset these higher costs (Rubera and Kirca, 2012). Therefore, effective planning and selection of innovative projects is probably one of the most challenging tasks facing any firm, particularly, firms engaging in radical innovations. Over one third of ideas generated for radical and more innovative projects emerge through formalised planned activities, conversely almost as many of the ideas generated for incremental projects emerge without specific guidance from a number of people as they do from more formalised, planned activities (Barczak *et al.*, 2009). Hence, when the task environment is more simplistic and certain, the need for structured, formal planning of a strategic nature is less important for the firm (Reboud *et al.*, 2014).

Research found that despite the level of technology within an industry, radical innovations have positive performance implications (Rubera and Kirca, 2012). Yet, incremental innovations rather than radical innovations are more evident in low-tech firms (Raymond and St-Pierre, 2010). Furthermore, research suggests that low-tech firms show weaker performance compared to their high-tech counterparts in terms of their product innovation performance (Kirner *et al.*, 2009), and suggests that firms in high-tech industries emphasise new product development to a greater extent than firms in low-tech industries (Quinn, 1979). Thus, we propose the following:

H3: *Formalised planning and selection is more positively associated with product innovation performance in high-tech industries with more radical innovations than in low-tech industries with more incremental innovations.*

Structure and performance

In the BPM, "structure" refers to the organisational structure of the firm, and "performance" refers to the way in which performance is described within the firm. Organisational structure is the formal configuration between individuals and groups in the organisation in terms of the allocation of tasks, responsibility and autonomy (Galbraith, 1987; Greenberg, 2011). Laitinen (2002) suggests that performance can be defined as the ability of an object to achieve results in a dimension determined, *a priori*, in relation to a target. Both structure and performance are known to impact the firm's product innovation performance (Cormican and O'Sullivan, 2004). Additionally, Barczak *et al.* (2009) found that the most successful firms have a management team that supports and facilitates innovation with appropriate structures, resources, and processes.

Research suggests that mechanistic organisational structures which are formalised, bureaucratic, inflexible and standardised are more appropriate to stable environments whereas more organic organisational structures which are informal, flexible, supportive, open to risk-taking and creativity are more appropriate in dynamic environments of changing conditions and unforeseen circumstances (Burns and Stalker, 1961; Hage, 1986; Cornwall and Perlman, 1990; Ireland *et al.*, 2009; Jennings, 1994; Menguc and Ahuh, 2010; Slevin and Covin, 1990). Furthermore, organisations that are more structured with greater rigidity have a lower degree of innovativeness (Adeyeye *et al.*, 2017). When a firm has expertise and tacit knowledge to successfully manage commercially viable projects, formal systems and planning structures may not have the same necessity (Reboud *et al.*, 2014). Perhaps unsurprisingly, therefore, research suggests that high-tech firms tend to have organic structures while low-tech firms tend to have more mechanistic structures (Covin *et al.*, 1990), organisational creativity for innovation require organic structures (Hisrich and Kearney, 2013). Because open, flexible and creative organic structures are more difficult to maintain, and to support, than bureaucratic, inflexible and standardised mechanistic structures, we argue that "organic structure" is more important to high-tech firms than to low-tech firms. Furthermore, because innovation is the easiest, and the fastest, when organisations have organic organisational structures (Damanpour, 1991), high-tech firms tend to be more innovative, and perform better than low-tech firms, in terms of innovation (O'Regan and Ghobadian, 2005). In terms of structure and performance, therefore, we argue that

H4: *The relationship between an organic structure and higher organisational performance is more positively associated with product innovation in high-tech industries than in low-tech industries.*

Communication and collaboration

In the BPM, "communication" describes the way in which the organisation manages its internal dialogue, and "collaboration" refers to its external collaborative links. Research suggests that product innovation is an information transformation process, according to which information is gathered, processed and transferred in a creative way (Cormican and O'Sullivan, 2004). Increased communication within the firm should therefore be positively and significantly related to product innovation performance. Communication is positively related with creativity, risk-taking (Antoncic and Hisrich, 2001), and initiative taking (Rese and Baier, 2011). Collaboration yields three major benefits for collaborating parties: (1) access to complementary resources, (2) better tacit and codified knowledge transfer and (3) lower risk and greater sharing of R&D costs (Faems *et al.*, 2005, p. 240). Collaboration provides the firm with access to new knowledge and new technology (Afuah, 2000; Lee *et al.*, 2001; McEvily and Zaheer, 1999; Rothaermel, 2001; Saxton, 1997; Singh and Mitchell, 1996; Stuart *et al.*, 1999). "Firms that collaborate technologically with suppliers have a greater propensity for product innovation" (Fossas-Olalla *et al.*, 2015, p. 1405). Collaboration with suppliers allows firms to decrease their risks and more effectively utilise time when developing new products, and thus enhance flexibility, product quality and adaptability to the market (Faems *et al.*, 2005; Mooi and Frambach, 2012; Ragatz *et al.*, 2002). As such, collaboration shapes the resource-based competitive advantage of the firm (Rumelt (1984); Wernerfelt, 1984). Pisano and Verganti (2008) state that the leaders in innovation will be those firms that identify the best way to leverage an external network.

The ability to utilise knowledge to a large extent depends on the routines and structures of the organisation, for example, the division of labour, the prevailing forms of communication (Cohen and Levinthal, 1990). In many low-tech firms, these practices are embedded in the work organisation that is centralised and based on a marked division of labour (Schmierl and Köhler, 2005). Innovation in low-tech industries sees collaboration and networking between companies as a way to overcome knowledge fragmentation and shape innovation-related activities in each company (Santamaria *et al.*, 2009). Therefore, the number of mechanisms for driving intercompany relationships are developed, such as customer–supplier linkages, mobility of employees as well as the firms' embeddedness in contextual, social and institutional relationships (Petrou and Daskalopoulou, 2009). However, research findings suggest that in high-tech firms, higher expenditure in R&D is positively associated with collaboration among more distant organisations (Jong and Freel, 2010). Hence, high-tech firms generally invest more into product R&D in comparison to their low-tech firm counterparts (Raymond and St-Pierre, 2010). Open communication as a way of information sharing and empowerment was recognised as a critical component of innovation (Pinchot, 1985). Furthermore, Hage (1986) argued that open communication channels are most appropriate for firms in technologically advanced environments. Consequently, we suggest that communication and collaboration should improve product innovation performance. Therefore, one would expect to find more interactive, open communication and collaboration leading to greater product innovation performance in high-tech firms in comparison to low-tech firms. Thus, we propose

H5: *More interactive, open communication and higher levels of collaboration is more positively associated with product innovation performance in high-tech industries than in low-tech industries.*

Methods

Sample

The study collected data from high- and low-tech firms operating within an economically homogenous region in the north of the Netherlands. EUROSTAT definitions (see Table 1) were employed to identify high- and low-tech industries. Using data from the local Chambers of Commerce (*Kamer van Koophandel*), a total sample of 549 firms was identified that included 319 high-tech and 230 low-tech firms. Contact numbers, email addresses and postal addresses were retrieved for each firm. The survey was emailed, requesting completion by senior managers with expertise in PIM. Research assistants were recruited to telephone each firm once, when the survey was first distributed, to ensure that the survey was sent to the correct person, a second time if the company did not complete the survey within one month, and a third time if the company did not complete the survey within three months. The survey instrument was in English. A total of 296 completed and usable questionnaires were returned within a three-month period. Respondents included 112 high-tech firms and 184 low-tech firms. The overall response rate for this study was 53% (296/549).

Measures

This study used Cormican and O'Sullivan's (2004) BPM. Using a five-point Likert scale, which ranges from 1 = "strongly disagree" to 5 = "strongly agree", the questionnaire requires managers to indicate the extent to which they agree or disagree with 50 questions or statements about their firm. Based on the manager's

Table 1. Eurostat definitions of high-, medium- and low-tech manufacturers.

	Medium-tech		
High-tech	Medium–High	Medium–Low	Low-tech
Pharmaceuticals	Chemicals	Petroleum products	Food
Computers	Weapons and ammunitions	Rubber and plastic	Beverages
Aerospace	Electrical equipment	Other non-metallic products	Tobacco
	Machinery	Basic metals	Textiles
	Motor vehicles	Ships and boats	Clothing

response, five independent variables were constructed: "*Strategy and Leadership*", "*Culture and Climate*", "*Planning and Selection*", "*Structure and Performance*" and "*Communication and Collaboration*". To determine how these factors affect the firm's innovation performance, managers were asked to evaluate the contribution of their products introduced in the previous three years, in relation to sales, profitability and customer satisfaction. This was used to create a sixth construct, the dependent variable: *product innovation performance*. The full survey is presented in Appendix 1. Because scores for the dependent variable varies between 6 and 30, while the scores for the 5 independent variables vary between 10 and 50, each of the 6 constructs were rescaled between 0 and 5.

Reliability and validity

A number of tests were performed to check the reliability of the data that the survey produces. First, we test for a non-response bias. The results suggest that there is no systematic difference between early, late, and non-respondents, and therefore we can conclude that the sample is representative. Second, we conduct a factor analysis on Cormican and O'Sullivan's (2004) five constructs and the innovation performance measure to ensure that these empirically untested measures are robust. Each of the five constructs is composed of 10 items, and the factor analyses revealed that, to generate single factors, a number of items had to be dropped from each construct. A single "*Strategy and Leadership*" factor was created out of survey elements 2, 3, 5, 6 and 7, a single "*Culture and Climate*" factor was created out of elements 2, 3, 4, 6 and 7, a single "*Planning and Selection*" factor was created out of elements 1, 2, 3, 4, 7, 8 and 9, a single "*Structure and Performance*" factor was created out of elements 1, 2, 4, 5, 6, 7, 8 and 9, and a single "*Communication and Collaboration*" factor was created out of elements 4, 5, 6 and 7. This suggests that while Cormican and O'Sullivan's (2004) constructs are theoretically valid, their measures needed to be adjusted to be appropriately used in an empirical setting. All items of the innovation performance measure, that is, the dependent load as expected. Finally, we calculate a Cronbach's alpha for the five constructs and for the innovation performance measures. Table 3 shows that all variables are reliable (with Crombach's $\alpha > 0.80$), and therefore all meet Nunnally's (1978) criteria for exploratory research.

Control variables

In addition, to the Cormican and O'Sullivan (2004) scale, we asked respondents to provide data for a number of controls. Using this, in our analysis, we control for (1) the size of the firm, using the natural log of the total number of full-time employees; (2) the age of the firm, using the natural log of the year that it officially began operating; (3) the province within which the firm is based and (4) the public/private status of the firm.

We model performance as

$$\begin{aligned}\text{Performance}_{\text{it}} = \beta_0 &+ \beta^1\text{Strat\_Lead}_{\text{it}} + \beta^2\text{Cult\_Clim}_{\text{it}} + \beta^3\text{Plan\_Select}_{\text{it}} \\ &+ \beta_4\text{Stru\_Perf}_{\text{it}} + \beta_5\text{Comm\_Collab}_{\text{it}} + \beta_6\text{Controls}_{\text{it}} + \varepsilon_{\text{it}},\end{aligned}$$

where (1) Performance is the *Product Innovation Performance* of firm i in period t; (2) Strat_Lead is the Strategy and Leadership construct of firm i in period t; (3) Cult_Clim is the culture and climate construct of firm i in period t; (4) Plan_Select is the planning and selection construct of firm i in period t; (5) Stru_Perf is the structure and performance construct of firm i in period t; (6) Comm_Collab is the communication and collaboration construct of firm i in period t; (7) Controls is the set of firm level controls described above for firm i in period t and (4) ε is a normally distributed error term. We estimate this equation using an ordinary least square (OLS) model.

Results

Descriptives

Table 2 presents an overview of the variables employed. It reports that the 296 firms are between 2 and 165 years old (mean 37), and employ between 3 and 987 employees (mean 176). The majority (85%) are private, and geographically, they are equally distributed across the three provinces of Groningen, Friesland and Drenthe. Table 3 presents summary statistics and construct reliability.

The general case

Models 1–7 on Table 4 report the first results.

Model 1 is the base specification of control variables. We check this specification for multi-collinearity using a variance inflation factor (VIF). The results reveal that the highest VIF for a single variable is 1.05, with a mean VIF of 1.03. These values are well below the established cut-off point of 5.3 (Hair *et al.*, 1992) and 10 (Studenmund and Cassidy, 1992), and as a result, we can conclude that multi-collinearity is not a concern.

Models 2–6 consider the isolated impact of Cormican and O'Sullivan's (2004) constructs on the firm's product innovation performance, and the results suggest that, individually, each construct has a positive and significant impact on product

Table 2. Descriptive statistics.

		Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9
1	Product innovation performance	3.48	0.93	0.00	5.00									
2	Strategy and leadership	3.79	0.70	0.00	5.00	0.46 (0.00)								
3	Culture and climate	3.67	0.64	0.00	5.00	0.46 (0.00)	0.74 (0.00)							
4	Planning and selection	3.80	0.71	0.00	4.89	0.37 (0.00)	0.64 (0.00)	0.75 (0.00)						
5	Structure and performance	3.68	0.71	0.00	5.00	0.42 (0.00)	0.59 (0.00)	0.75 (0.00)	0.79 (0.00)					
6	Communication and collaboration	3.88	0.73	0.00	5.00	0.47 (0.00)	0.55 (0.00)	0.64 (0.00)	0.76 (0.00)	0.78 (0.00)				
7	Firm size	176.76	231.04	3	987	−0.01 (−0.85)	−0.12 (−0.05)	−0.04 (−0.45)	−0.09 (−0.14)	0.01 (−0.84)	−0.02 (−0.68)			
8	Firm status	0.15	0.36	0	1	0.01 (−0.90)	−0.01 (−0.84)	0.09 (−0.11)	0.13 (−0.03)	0.21 (0.00)	0.16 (−0.01)	0.14 (−0.02)		
9	Firm region	1.92	0.80	1	3	−0.07 (−0.20)	−0.21 (0.00)	−0.01 (−0.84)	−0.04 (−0.53)	−0.03 (−0.65)	−0.01 (−0.89)	0.01 (−0.83)	0.04 (−0.47)	
10	Firm age	37.41	34.88	2	165	−0.01 (−0.84)	0.11 (−0.05)	−0.13 (−0.03)	0.00 (−0.99)	−0.10 (−0.10)	0.03 (−0.60)	−0.10 (−0.09)	−0.13 (−0.03)	−0.10 (−0.08)

Correlation coefficients. Significance levels in parentheses.

Table 3. Summary statistics, construct reliability.

Variable	Mean[a]	Standard deviation	Cronbach's alpha
Product innovation performance	3.48	0.925	0.903
Strategy and leadership	3.78	0.695	0.822
Culture and climate	3.66	0.641	0.817
Planning and selection	3.80	0.708	0.877
Structure and performance	3.68	0.705	0.866
Communication and collaboration	3.88	0.730	0.878

Note: [a]Mean construct values across respondents on Likert-scales ranging from "1" = ". . .. is strongly disagree" to "5" = ". . .. is strongly agree".

innovation performance. Model 7 includes the five constructs in a single equation, and reports that, in this context, *Structure and Performance* does not significantly impact product innovation performance.

High- vs. low-tech firms

Models 8 and 9 on Table 4 reports considerable variations across industry type. Again, we first test (results available upon request), the isolated impact of Cormican and O'Sullivan's (2004) constructs, to confirm that each construct has an isolated effect on the firm's product innovation performance. Models 8 and 9 incorporate the five constructs in a single equation. A number of results are noteworthy.

First, it is interesting to see that, of the five constructs, only three are significant in the low-tech firms — *Culture and Climate, Structure and Performance*, and *Communication and Collaboration* — while in the high-tech firms, only two are significant — *Strategy and Leadership* and *Communication and Collaboration*. This suggests that high- and low-tech managers that attempt to implement all five factors, simultaneously, can expect very different returns on their efforts. The fact that one of the five factors — *Structure and Performance* — has a negative and significant effect on performance for low-tech innovation shows the danger of assuming that "one size fits all".

Second, because the parameter estimates for the high- and low-tech firms seem to suggest that some factors have a stronger impact on one side than on the other, we compare the regression coefficients. We interact a high-tech dummy (High) with each of the five constructs, to test the null hypothesis that the regression coefficient for high- and low-tech is the same. Table 5 reports the results. Models 10–14 test each of the constructs individually, and Model 15 includes the five constructs in a single equation. In Models 10–14, the

Table 4. OLS—full sample.

Variables	Model 1 base	Model 2 all	Model 3 all	Model 4 all	Model 5 all	Model 6 all	Model 7 all	Model 8 High-tech	Model 9 Low-tech
Strategy and leadership		0.628***					0.309***	0.939***	−0.149
		(0.0718)					(0.109)	(0.173)	(0.138)
Culture and climate			0.669***				0.268*	0.128	0.341**
			(0.0758)				(0.143)	(0.228)	(0.166)
Planning and selection				0.510***			0.264**	−0.239	0.0684
				(0.0728)			(0.126)	(0.180)	(0.175)
Structure and performance					0.569***		0.00308	−0.0304	−0.411**
					(0.0714)		(0.130)	(0.195)	(0.166)
Communication and collaboration						0.623***	0.496***	0.286*	0.624***
						(0.0662)	(0.110)	(0.145)	(0.159)
Firm size (log)	−0.0187	0.0256	0.00973	0.0309	0.0106	0.00376	0.00683	−0.0725	0.0232
	(0.0438)	(0.0394)	(0.0391)	(0.0412)	(0.0399)	(0.0385)	(0.0380)	(0.0614)	(0.0437)
Firm status	0.0293	0.00837	−0.0886	−0.129	−0.216	−0.191	−0.123	−0.311	−0.0500
	(0.153)	(0.136)	(0.137)	(0.144)	(0.142)	(0.136)	(0.134)	(0.193)	(0.162)
Firm region	−0.0833	0.0308	−0.0794	−0.0678	−0.0685	−0.0752	−0.0272	0.183	0.0165
	(0.0676)	(0.0616)	(0.0601)	(0.0627)	(0.0614)	(0.0593)	(0.0602)	(0.112)	(0.0625)
Firm age (log)	−0.0401	−0.0701	0.00564	−0.0657	−0.0307	−0.0841	−0.0583	0.285***	−0.0759
	(0.0589)	(0.0526)	(0.0527)	(0.0547)	(0.0535)	(0.0519)	(0.0525)	(0.0893)	(0.0623)
Constant	3.538***	1.012***	1.230***	1.681***	1.536***	1.132***	0.408	−0.185	1.440**
	(0.211)	(0.345)	(0.322)	(0.330)	(0.316)	(0.316)	(0.346)	(0.488)	(0.593)
N	296	296	296	296	296	296	296	112	184
R-squared	0.008	0.215	0.217	0.151	0.186	0.240	0.305	0.633	0.170

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. Quantifying the difference between high- and low-tech firms.

	Model 10 all	Model 11 all	Model 12 all	Model 13 all	Model 14 all	Model 15 all
Strategy and leadership	0.146**					0.212*
	(0.130)					(0.14)
INT_High* Stratlead	0.852***					1.129***
	(0.150)					(0.21)
Culture and climate		0.449***				0.407**
		(0.120)				(0.17)
INT_High *Cultclimate		0.541***				0.491*
		(0.150)				(0.27)
Planning and selection			0.397***			0.018
			(0.130)			(0.19)
INT_High *Planselection			0.352**			−0.233
			(0.160)			(0.25)
Structure and Performance				0.261**		0.329*
				(0.120)		(0.17)
INT_High *Structper				0.525***		0.378
				(0.150)		(0.25)
Communication and collaboration					0.531***	0.565***
					(0.130)	(0.17)
INT_High *Commcoll					0.147**	0.235
					(0.150)	(0.22)
High-tech dummy	−2.605***	−1.383**	−0.735	−1.480***	−0.193	−1.532**
	(0.580)	(0.570)	(0.610)	(0.560)	(0.580)	(0.68)
Firm size (log)	0.019	−0.016	0.016	−0.018	−0.017	0.003
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.04)
Firm status	−0.046	−0.123	−0.192	−0.214	−0.220	−0.101
	(0.120)	(0.130)	(0.140)	(0.140)	(0.130)	(0.12)
Firm region	0.119**	0.003	−0.016	−0.007	−0.052	0.047
	(0.060)	(0.060)	(0.060)	(0.060)	(0.060)	(0.06)
Firm age (log)	0.066	0.090*	0.011	0.006	−0.035	0.049
	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.05)
Constant	2.694***	1.746***	1.899***	2.388***	1.331**	1.600***
	(0.540)	(0.460)	(0.540)	(0.470)	(0.520)	(0.61)
N	296	296	296	296	296	296
*R*_Square	0.370	0.330	0.250	0.270	0.280	0.437

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

interaction terms are significant, suggesting significant differences in the impact of these constructs on the high- and low-tech firms. The coefficient for the high-tech dummy variable demonstrates, in each case, the difference between the two sectors. In Model 15, only two of the interaction terms — *Strategy and*

Leadership and *Culture and Climate* — remain significant. Individually, therefore, we can conclude that there are significant sectorial differences in terms of the impact of each of the five constructs but together, and controlling for the other factors only *Strategy and Leadership* and *Culture and Climate* have a statistically different effect.

Discussion and Implications

Previous research has called for greater understanding of innovation in the low-tech sector (Hirsch-Kreinsen, 2008), yet few have conducted research in line with this call to deepen our understanding of key similarities and differences between PIM in high- and low-tech manufacturing firms. This study contributes to our understanding by empirically analysing the product innovation performance of high- and low-tech firms in the Netherlands. Using firm-level data, it has shown firstly that the classification into high- and low-tech industries is necessary to reflect the reality of the firms belonging to these industries as regards their respective PIM intensity. Our findings offer an important contribution to the PIM literature by illustrating the impact of assuming that "one size fits all" in high- and low-tech industries. This research demonstrates that a limited field of vision stemming from the assumption that "one size fits all" may have obscured critical nuances in PIM within high- and low-tech firms. This study specifically extends the existing research on PIM in high- and low-tech industries in several important ways. An interesting storyline emerging from the observed pattern of results in empirically testing Cormican and O'Sullivan's (2004) model shows that while each of their constructs has a statistically significant effect on performance, when implemented individually, only four of the five survive a multivariate analysis. This implies that managers of high- and low-tech firms should look to implement the five constructs individually. Most significantly, because of this high heterogeneity between the two sectors, the analysis of the effects of PIM intensity on product innovation performance needs to be conducted separately between high- and low-tech industries because they are distinct sectors. Taking account of the uniqueness of the sectors managers' in high- and low-tech firms should expect different returns on their efforts.

Additionally, if implications were to be drawn based on testing the general case, using the full sample, we find that all five constructs have a part to play in effective PIM. This supports Cormican and O'Sullivan's (2004) hitherto untested thesis. However, when we divide the sample into high- and low-tech firms, we report a number of important sectorial similarities and differences in PIM. More significantly by contrasting the effects of the five constructs on samples of high- and low-tech firms, we demonstrate the limitations within the existing literature. That is, our sample suggests that "one size does not fit all", in terms of innovation management and, most importantly managers' of low-tech firms cannot rely fully upon the literature developed on the high-tech firms.

Looking at the differences in the management of high- and low-tech firms, we report a number of interesting results. We find significant differences in the impact of these five constructs, on the two types of firms, and conclude therefore that the importance of the factors is not constant. Looking at the univariate analyses in order to consider the effect of implementing each of the five factors individually, we note that each of the five has a positive and significant effect in both the high- and low-tech cases. We observe that the five factors are important for high- and low-tech managers, and suggest that managers should look to implement the five constructs, separately, but in doing so should expect different returns on their efforts. Both high- and low-tech managers can use these constructs to improve their product innovation performance.

Most noteworthy, taking the multivariate case, to consider the effect of implementing the five factors simultaneously, we note that very different factors survive the analysis, and that the differences are statistically significant. This suggests, again, that managers of high- and low-tech firms that implement all five factors can expect very different results. The fact that one of the five factors has a negative effect for low-tech PIM indicates that low-tech firms put a different emphasis on PIM and highlights further concerns of assuming that "one size fits all". We conclude, therefore, that blindly following theory can not only have a suboptimal effect on product innovation performance in the low-tech sector, but also, it may even have a negative effect. Furthermore, interacting a dummy variable to quantify the differences in the effect of the construct reports a number of statistically significant differences, for the impact of the five constructs in each of the two sectors. This again highlights the fact that managers of high- and low-tech firms can expect different returns on their efforts.

Finally, our findings show that there are not only differences between high- and low-tech firms, but also a number of similarities in high- and low-tech PIM. Interestingly, we show that the *Communication and Collaboration* construct is the only construct from the five to be positive and significant in all models. Thus, while there are questions about the differences between the management of high- and low-tech firms, the importance of *Communication and Collaboration* in innovation remains unquestionable. These conclusions support and further expand the discussion on PIM, and draw conclusions relevant to managers, innovators and academics in the field.

Limitations and Directions for Future Research

The current study's results and associated implications should be viewed in the light of the study's limitations. While this study represents a progressive step, certainly there is still much work to be done. First, the sample for this study was comprised solely of Dutch-based firms, so the generalisability of the findings may be limited both geographically and in scope. Further research could examine these relationships in other cultural contexts. Second, this study is building on Cormican and O'Sullivan's (2004) survey of the factors that influence product innovation performance in high-tech firms. By doing so, however, it may be that we overlook unique factors, specific to low-tech-specific manufacturers. In other words, by describing the low-tech sector in terms of the high-tech sector, in an effort to describe the limits of a literature developed on the basic of the high-tech sector, we may unintentionally propagate the problem that we seek to address. Our results support this suggestion, as the *R*-square for the high-tech firms (0.633, Model 8) is much higher than the *R*-square for the low-tech firms (0.170, Model 9). We hope that future research will pick up on this issue, and directly exploring the factors that predict product innovation performance in the low-tech sector.

Moreover, methodologically, the measures utilisation in this study is by no means exhaustive, and their operationalisation may not fully capture all the facets. Further studies could identify other dimensions and examine the validity of the proposed relationships in more detail. Another promising area concerns studying innovation strategies' in high- and low-tech firms, longitudinal dynamics, which may have a long-term effect on product innovation performance.

Furthermore, it must be recognised that there are profound technological differences between industries, even those that are regarded as "high-tech" industries for example innovative car producers such as Tesla or Google's self-driving car project require very different technologies (for example, batteries, software design, digitisation, artificial intelligence) from other "high-tech" industries (for example, genomic processing, nanotechnology). They adopt very different business models, and structure their innovation development in very different ways. Future research may continue down this path by investigating the specific technological differences within specific high- and low-tech industries and embrace a more holistic approach to theorising on how favourable PIM circumstances productively align within the specific context of different high- and low-tech industries.

Finally, the applicability of our findings depends upon the richness which deeper contextualisation affords. In this vein, time has come to more fully consider how PIM theory may best serve the practitioner community. In practice, it is reasonable to speculate that managers will be more likely to trust as well as benefit from more nuanced models and narratives. When is it best to invest in innovation and to what extent? This study communicates the narrative that "one size does not fit all" in terms of PIM in high- and low-tech firms. Certainly, other key considerations exist within the PIM — performance narrative in high- and low-tech firms, and thus executives will demand more sophisticated understandings that include a wider range of additional factors that may not have already been considered in the previous research. Understanding when, where and how to innovate is based on PIM and the firm's attributes and environmental considerations remains a central managerial task.

Appendix A. Cormican and O'Sullivan's (2004) Survey

What company do you work for? ____________________________________

To what extent do you agree or disagree with these statements where 1 represents strongly disagree and 5 represents strongly agree?

In general, the company's new products in the last three years contributed to

(1)	Sales relative to the major competitors	1 2 3 4 5
(2)	Sales relative to the original objectives	1 2 3 4 5
(3)	Profitability relative to the major competitors	1 2 3 4 5
(4)	Profitability relative to the original objectives	1 2 3 4 5
(5)	Market share relative to the major competitors	1 2 3 4 5
(6)	Customer satisfaction relative to the major competitors	1 2 3 4 5

Please circle the extent to which you agree or disagree with these statements where 1 represents strongly agree and 5 represents strongly disagree

Strategy and leadership

(1)	The product strategic plan is effective and used	1 2 3 4 5
(2)	Product strategy is clearly defined and communicated to all employees	1 2 3 4 5
(3)	The product innovation programme has a long term thrust and focus	1 2 3 4 5
(4)	Product strategy is used to align priorities with other functions	1 2 3 4 5
(5)	Strategies are flexible enough to respond to changes in the environment	1 2 3 4 5
(6)	Senior management is accountable for new product results	1 2 3 4 5

(7) Leaders visibly drive innovation 1 2 3 4 5
(8) Leaders adopt a consensus and shared approach to decision-making 1 2 3 4 5
(9) Leaders adopt a participative decision-making style 1 2 3 4 5
(10) Senior management actively encourages the submission of new product ideas 1 2 3 4 5

Culture and climate

(1) The organisation permits the emergence of intrapreneurs or product champions 1 2 3 4 5
(2) The organisation provides support in terms of autonomy, time and rewards 1 2 3 4 5
(3) Money is made available for internal projects 1 2 3 4 5
(4) Adequate resources are available and committed to achieve project goals 1 2 3 4 5
(5) All employees participate in generating ideas 1 2 3 4 5
(6) Senior management is committed to risk-taking in product innovation 1 2 3 4 5
(7) Failures and mistakes are tolerated and not punished 1 2 3 4 5
(8) Knowledge sharing is encouraged and rewarded 1 2 3 4 5
(9) All operations are driven by customer needs 1 2 3 4 5
(10) There is a formal idea generation process in place 1 2 3 4 5

Planning and selection

(1) An effective product innovation process is consistently implemented 1 2 3 4 5
(2) A formal process is used to determine and update project priorities 1 2 3 4 5
(3) Concepts are selected using pre-defined, multiple and explicit criteria 1 2 3 4 5
(4) Pre-development market and feasibility studies are rigorously undertaken 1 2 3 4 5
(5) Projects are terminated if and when necessary 1 2 3 4 5
(6) Project proposals are tested for alignment with organisational goals 1 2 3 4 5
(7) The project and the spending breakdown mirrors the organisations goals and measures 1 2 3 4 5
(8) There is a good balance of projects which maximises the value of the portfolio 1 2 3 4 5

(9) The product portfolio is matched to the firm's competencies and capabilities 1 2 3 4 5
(10) The voice of the customer is built into all product innovations 1 2 3 4 5

Structure and performance

(1) Projects are developed using effective cross-functional teams 1 2 3 4 5
(2) Project teams are organic, flexible and agile 1 2 3 4 5
(3) All team operations are driven by customer needs 1 2 3 4 5
(4) Team leaders are involved in setting the product performance objectives 1 2 3 4 5
(5) All team members are mutually accountable 1 2 3 4 5
(6) Team members are empowered to make decisions 1 2 3 4 5
(7) Virtual team members are equipped with effective ICT tools 1 2 3 4 5
(8) Team members' rewards are equitable 1 2 3 4 5
(9) Performance indicators are aligned with the organisations goals 1 2 3 4 5
(10) Performance indicators encourage desired behaviour 1 2 3 4 5

Communication and collaboration

(1) Gatekeepers are in place to continuously span the external environment 1 2 3 4 5
(2) Customers and suppliers are involved in the product innovation process 1 2 3 4 5
(3) Alliances are often formed with other organisations for mutual benefit 1 2 3 4 5
(4) Communications among team members is efficient and effective 1 2 3 4 5
(5) Communications between project teams is efficient and effective 1 2 3 4 5
(6) Information on ideas generated, problems raised and project status is accessible 1 2 3 4 5
(7) User needs analyses are undertaken and communicated to all 1 2 3 4 5
(8) Product strategy and performance measures are clearly communicated to all 1 2 3 4 5
(9) Individual skills are effectively leveraged within and between project teams 1 2 3 4 5
(10) Virtual team members seamlessly communicate with each other 1 2 3 4 5

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