THE OUTCOME OF DESIGN INNOVATION AND THE ANTECEDENTS OF DESIGN ACTIVITIES

THE OUTCOME OF DESIGN INNOVATION AND THE ANTECEDENTS OF DESIGN ACTIVITIES:

INSIGHTS FROM CANADIAN MANUFACTURING INDUSTRIES

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LAY ABSTRACT

Design plays a critical role in firms' product development and business strategies. Traditionally, technology innovation has been the focus of new product development. In recent years, scholars have begun to see design innovation as another vital innovation element of a new product. In this dissertation, two empirical studies have been conducted to examine the outcome of design innovation and the antecedents of design activities, respectively.

There are two key goals of this dissertation. The first goal is to understand the outcome of design innovation and what other factors jointly contribute to the outcome. The second goal is to understand what strategies that firms adopt lead to design activities. Answers to the first question show the performance implication of design innovation and the factors that drive the performance. Meanwhile, answers to the second question shed light on the firm strategies that drive design activities, which may lead to the introduction of design innovation. Empirical studies that tackle these questions are sparse.

ABSTRACT

The importance of product design has been getting attention in the past decade from scholars and practitioners. Design plays a critical role in firms' product development and business strategies. In recent years, scholars began to see design innovation as another vital innovation element of a new product. A new product should encompass at least two innovation elements: technology innovation and design innovation. While technology points to the function of a product, design points to the form of a product. Despite the advocacy of scholarly examination of design innovation, there are few studies of design innovation.

In this dissertation, two empirical studies have been conducted to examine the outcome of design innovation and the antecedents of design activities, respectively. Study 1 examines the effect of design innovation (as well as technology and service innovation) on new product performance. Additionally, the study examines the roles of marketing innovation and process innovation in mediating the relationships between these innovation activities and new product performance. Study 2 examines how firms' absorptive capacity, competitive responsiveness, and product development resources drive design and R&D activities. Design and R&D activities typically lead to the introduction of design and technology innovation.

Regarding the findings from this dissertation, the first study shows that design, technology, and service innovation (which, argued by this study, are the three main

innovation elements of a new product) all contribute to new product performance. Additionally, marketing innovation and process innovation are found to mediate the relationship between these innovation elements and performance.

The second study shows that a firm's competitor responsiveness, absorptive capacity (captured by "institutional sources" and "market sources of information"), and product development resources (captured by "cross-functional design team", "design or information control technologies", and "concurrent engineering") are positively related to firms' design and R&D activities.

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Chapter 1

Introduction

Firms and brands have recognized the importance of good product design in recent years. Brands such as Swatch demonstrate how new design transforms a product and even alters its meaning and expression (Verganti, 2008). Innovative and original product design differentiates firms' product offerings, leading to firms' sustainable competitive advantage. Design innovation is becoming a topic that is gaining significance and attention in the field of industrial marketing and new product development. Product design refers to all form- or aesthetics-related elements of a product, including "shape, proportion, materials, and color" (Micheli & Gemser, 2016, p. 613).

The literature on design innovation emphasizes that design innovation is the change (or sometimes the "degree of change") that is introduced only in a product's form but not in its function (Dan, Spaid, & Noble, 2018; Micheli & Gemser, 2016; Rubera, 2015; Rubera & Droge, 2013; Talke, Salomo, Wieringa, & Lutz, 2009). The change made in a product's functionality is considered as technology innovation (e.g., Rubera & Droge, 2013). In other words, design innovation only refers to the change in product aesthetics, whereas technology innovation only refers to the change in product functionality (Dan et al., 2018; Micheli & Gemser, 2016; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009).

There are only a few quantitative studies that have investigated the relationship between design innovation and business success (e.g., Micheli & Gemser, 2016; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009), despite all the studies that attempt to understand the mechanism and payoff of good design. In addition to the empirical evidence that shows a positive relationship between design innovation and firm performance, researchers have also examined the potential mediators and moderators in this design innovation–performance relationship. According to their studies, adherence to a design tradition (Micheli & Gemser, 2016), brand strength and brand advertising expenditure (Rubera, 2015), and branding strategy (Rubera & Droge, 2013) are found to moderate the design innovation–firm performance relationship, while expert and media recognition (Micheli & Gemser, 2016) is a mediator in this relationship. In addition, understanding the sources and incubators of design innovation is critical to advance the knowledge of design as a strategy. For example, a recent study from Dan et al. (2018) has shown market environment variables such as market size and market growth are related to design innovation. Studies that examined the antecedents of design innovation are sparse though. As such, the field of design innovation is still immature and in early-stage, inviting more studies to expand knowledge in this field.

In this context, I propose two studies that examine the outcome of design innovation and the antecedents of design activities, respectively. The first study seeks to understand the impact of design innovation, technology innovation, and service innovation on new product performance. I argue that a new product encompasses three types of innovation—design, technology, and service innovation—each one potentially contributing to the new product performance. Second, I attempted to examine the potential intermediate roles of marketing innovation and process innovation in this new product (captured by design, technology, and service innovation)–performance relationship. Marketing is responsible for "exploiting" the value of new products (Bartoloni & Baussola, 2016; King, Slotegraaf, & Kesner, 2008), and process concerns how firms manufacture new products (Piening & Salge, 2015). Marketing innovation and process innovation are the innovation activities that firms introduce to "exploit" and manufacture new products better. Since a new product (concerning design, technology, and service innovation) may call for changes in the ways it is manufactured and brought to the market (Bartoloni & Baussola, 2016; Damanpour & Gopalakrishnan, 2001; Piening & Salge, 2015), design and technology innovation (as well as service innovation) may first lead to marketing and process innovation and, in turn, new product performance.

The research objective of the first study is to take a holistic view examining how design, technology, and service innovation impact marketing and process innovation and how they jointly contribute to new product performance. The first study argues that design, technology, and service innovation are the three main types of innovation that form a new product and drive new product performance. Moreover, this study adopts the lenses of marketing capability and dynamic capability. This study proposes that design, technology, and service innovation also spur marketing innovation and process innovation, which subsequently contribute to new product performance. In other words, marketing innovation and process innovation are the potential mediators in this new product–performance model. The holistic framework that captures the new product (encompassing design, technology, and service innovation)–performance relationship and the potential mediating roles of marketing and process innovation in this relationship constitute the key contribution of this study.

For the second study, I attempted to examine the potential antecedents of design activities as well as research and development (R&D) activities, which usually lead to the introduction of design and technology innovation (OECD, 2005). While design is the focus of this study, examining design innovation and technology innovation simultaneously is suggested by the design innovation literature (e.g., Dan et al., 2018; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009). I adopted the perspectives of competitive strategies, absorptive capacity, and resource-based view (RBV) to examine the potential antecedents of design as well as R&D activities. These strategic aspects are highly relevant to the decision of design activities, investment, and eventually innovation introduction, but they have not been synthesized and empirically examined by any design study yet. This second study thus aims to fill the gap.

The literature that examines the antecedents of design is sparse, except for the study from Dan et al. (2018). Dan et al. (2018) mainly focused on market environment factors and their relationships to design innovation. I focused on firms' strategic factors that drive design activities. The second study shows evidence of how competitor responsiveness, absorptive capacity, and product development resources are related to design activities as well as R&D activities. Though fragmentedly discussed by different design-related papers, these aspects critical to design as a strategy have not been integrated and empirically examined through a quantitative study. The second study also provides insights into how competitor responsiveness, absorptive capacity, and product development resources impact design and R&D activities differently. Such insights may facilitate an understanding of different mechanisms underneath firms' decisions to conduct design activities compared to R&D.

Overall, the two studies advance the understanding of design innovation as a "distinct type of innovation" (e.g., Dan et al., 2018, p. 1496) and design as "an innovation strategy" (e.g., Czarnitzki & Thorwarth, 2012, p. 880). It makes a particular contribution to the body of literature on design innovation, a field still in its infancy yet getting more significance. Understanding design as an innovation type and strategy facilitates researchers' general understanding of innovation (e.g., Dan et al., 2018). It deepens the knowledge of product design since design is also considered a vital dimension of new product development. Moreover, since investing in design delivers value to business firms and customers, understanding what spurs design activities is vital for firms' performance.

The two studies will mainly draw on the data from Canada's *Survey of Innovation and Business Strategies (SIBS).* The SIBS follows the Oslo Manual and is comparable to the Community Innovation Survey (CIS), which is widely used by innovation and business scholars globally. Oslo Manual provides guidelines "for the collection and interpretation of data on innovation" (OECD, 2005, p. 14). The findings of two studies are based upon approximately 2000 firms that cover all Canadian manufacturing industries. As the extant design innovation studies mainly focus on a particular industry (e.g., automobile or furniture industry), which limits the understanding of design innovation, this study advances the knowledge of design innovation based on evidence from all manufacturing industries. In addition, this study brings in reliable and recognized measures of innovation and performance (i.e., based on OECD guidelines) that have not been used by the existing design innovation literature yet, thus contributing to the design innovation literature stream. Since the SIBS is designed based on OECD guidelines and is comparable to the CIS studies that various countries have adopted, it opens the possibilities for comparative studies to advance the understanding of design innovation topics in the future.

Chapter 2

Study 1

Examining the Effects of Design, Technology, and Service Innovation on New Product Performance: The Mediating Roles of Marketing and Process Innovation

2.1. Literature Review

Innovation and new product research studies have widely discussed and examined technology innovation. Technology innovation has been spotlighted in new product-related studies (Rubera & Droge, 2013; Verganti, 2006). Only in the recent decade has the topic of design gotten attention and significance. Scholars argue that design innovation is a "neglected dimension" of a new product (e.g., Talke et al., 2009, p.601). They posit that new products are constituted by technology innovation and design innovation (Rubera & Droge, 2013; Verganti, 2006). Researchers started to explore the concept, role, and scope of design and, more importantly, how design creates value for customers and organizations (e.g., Candi, 2016; Chiva & Alegre, 2009; Micheli & Gemser, 2016; Rubera, 2015; Rubera & Droge, 2013). Several studies have pioneered in examining the performance implications of design innovation, shown in Table 1 (Micheli & Gemser, 2016; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009). These studies all focused on manufactured goods which allow a clear distinction between design innovation and technology innovation. Design innovation is distinguished from technology innovation as design innovation points to the change in a product's form (or aesthetics), whereas technology innovation points to the change in a product's functionality (or utility) (Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009). In other words, design innovation and technology innovation constitute the main innovative elements of a new product (Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009).

The research findings from empirical studies on design innovation are mainly summarized in Table 1. Design innovation (or innovativeness) enhances firms' performance which can be market share, profitability, or sales (Micheli & Gemser, 2016; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009). Design tradition, brand strength and brand advertising expenditure, and branding strategy are the moderators in the relationship between design innovation (or innovativeness) and performance (Micheli & Gemser, 2016; Rubera, 2015; Rubera & Droge, 2013). Expert and media attention mediates the relationship between design innovativeness and financial performance (Micheli & Gemser, 2016). Besides, Dan et al. (2018) explored the antecedents of design innovation and found that investment in R&D, market size, and market growth are the factors that lead to design innovation.

In addition to the studies of design innovation, scholars have also explored different design strategies and phenomena and their relationships to performance (shown in Table 1). Evidence shows that design effectiveness, design intensity, design investment, design emphasis as well as resources are all positively related to firms' performance (Candi, 2016; Chiva & Alegre, 2009; Gemser & Leenders, 2001; Hertenstein, Platt, & Veryzer, 2005).

Design in-house (versus externally) is found to contribute to firms' innovation performance (Czarnitzki & Thorwarth, 2012). The event study from Boyd and Kannan (2018) shows that third-party recognition for design excellence could impact firms' market value. Jindal, Sarangee, Echambadi, and Lee (2016) examined the tradeoffs of functional design, form design, and ergonomics design in their relationships to firms' market share.

The development of design innovation studies demonstrates that scholars have a strong interest in understanding the performance implications of design innovation and the factors that potentially mediate or moderate how design innovation is related to performance. Talke et al. (2009) argued that design newness should be a necessary dimension in the discussion and evaluation of product innovativeness. Other scholars (e.g., Micheli & Gemser, 2016; Rubera, 2015; Rubera & Droge, 2013) started to adopt the same approach that views design innovation as a new dimension of new products. Although technology innovation was (and maybe is still) the focus of new product and innovation studies, design innovation is now also in the scope as scholars discuss and examine new products.

The literature discussing service's role and how service may complement and differentiate product offerings is also gaining significance (e.g., Gebauer & Friedli, 2005; Santamaría, Nieto, & Miles, 2012; Vandermerwe & Rada, 1988). The case study of the Coasting bike (Brown, 2008) may showcase the potential significance of service in new product development. As the product development team introduced the concept of Coasting bike (a bike with an interesting and innovative design), they also came up with the idea of creating a website that mapped out safe biking paths for consumers (Brown, 2008). Service innovation, generally defined as "a new service" (Witell, Snyder, Gustafsson, Fombelle, & Kristensson, 2016, p. 2868), could result from a user-centric mentality in product development which aims to increase customers' holistic experience using the new products (e.g., Brown, 2008).

In this context, I propose that new (manufactured) products also encompass service innovation, in addition to technology and design innovation. In the manufacturing industries, firms often bundle products and services together to differentiate their offerings and enhance firms' competitive advantages (e.g., Gebauer & Friedli, 2005; Vandermerwe & Rada, 1988). Service innovation (i.e., new service) could be offered along with new products (Vandermerwe & Rada, 1988; Witell et al., 2016). Service innovation could be an essential component of new product offerings (e.g., the case of the Coasting bike from Brown (2008)). Scholars have argued that design innovation is a "neglected dimension" of new products (Talke et al., 2009, p. 601). Is service innovation another perspective that I can explore when assessing new products? Thus, I propose to investigate service innovation and its relationship with new product performance as well. In other words, I intend to bring attention to the innovation and new product development literature that service innovation is another important dimension of new products.

As new products are developed, the essential activities afterward are to bring the new products to the market, and this means new marketing and production methods might be required to deliver the new products to the market and consumers effectively and efficiently (e.g., Bartoloni & Baussola, 2016; Damanpour & Gopalakrishnan, 2001; Pisano, 1997; Ramirez, Parra-Requena, Ruiz-Ortega, & Garcia-Villaverde, 2018; Reichstein & Salter, 2006). Marketing innovation (i.e., new marketing methods) could "exploit the potential gain" of new products (e.g., Bartoloni & Baussola, 2016, p. 92). And process innovation (i.e., new production process) may facilitate the effective production of new products (Piening & Salge, 2015). In theory, firms that achieve marketing as well as process innovation to facilitate new products should see higher new product performance. However, there are controversial perspectives on whether different innovation activities create synergistic or dis-synergistic effects (e.g., Grimpe, Sofka, Bhargava, & Chatterjee, 2017; Lee, Lee, & Garrett, 2017). From a resource perspective, firms' decisions and investments in multiple innovation introductions are relevant to resource allocation. Multiple innovation activities may result in resource conflicts (e.g., Grimpe et al., 2017). Understanding the interrelationships of different innovation activities may shed light on the managerial implications of resource allocation (Rubera & Droge, 2013).

In this context, I propose investigating the potential intermediate roles of marketing innovation and process innovation in the new product (including design, technology, and service innovation)–performance relationship. Marketing capabilities create values for new products and firms (e.g., Krasnikov & Jayachandran, 2008), and marketing innovation (i.e., novel marketing methods) can be seen as a higher level of marketing capability (Danneels, 2002; Grimpe et al., 2017). Grimpe et al. (2017) argued that new marketing activities and new products are not necessarily complementary but may create dis-synergistic effects. Introducing various innovation activities is not necessarily advantageous to firms (Grimpe et al., 2017). Another perspective suggests that innovative marketing methods could "exploit the potential gain" of new products (e.g., Bartoloni & Baussola, 2016, p. 92), which is the perspective adopted by my study. Thus, I propose to examine marketing innovation as a potential mediator in the new product–performance relationship.

In addition, the existing design innovation studies haven't examined the interplay of design innovation and process innovation (i.e., new production, supply chain, and administrative processes (Piening & Salge, 2015). Since process innovation is mainly perceived as a cost-reduction strategy (e.g., Piening & Salge, 2015), one might argue that fixed product design is related to process innovation for large-scale production (e.g., Reichstein & Salter, 2006). However, studies have also shown that innovative design is closely related to production and supply chain (e.g., D'Ippolito, Miozzo, & Consoli, 2014). Thus, I propose to examine process innovation and its interplay with design, technology, and service innovation as well.

Table 1

Existing Empirical Studies That Examine Design (Innovation)–Performance Relationship

Study	**Outcome**	**Independent variable**	**Moderator**	**Mediator**	**Research questions/objectives**	**Scope and sample size**
	Design innovation–performance studies					
The present study	New product performance	Design innovation; Technology innovation; Service innovation		Marketing innovation; Process innovation	1.Whether design innovation, technology innovation and service innovation contribute to new product performance; 2. Whether marketing innovation and process innovation are the	All manufacturing industries; n = 2000 firms

					mediators in the above relationships.	
Micheli and Gemser (2016)	Financial performance (market share, profitability, and turnover)	Design innovativeness	Design tradition	Expert and media attention	“Whether specific types of signals can mitigate potential drawbacks of innovative designs” (p. 614).	Furniture industry; *n* = 79 NPD projects
Rubera (2015)	Sales	Design innovativeness; Technological innovativeness	Brand strength and brand advertising expenditure		1. “How does design innovativeness influence product sales’ evolution over time?” (p. 98); 2. “What is the joint influence of design and	Car (*n* = 2,757 model-year); Motorcycle (*n* = 2,847 model-year)

					technological innovativeness on sale?" (p. 98); 3. "How do brand strength *before* launch and brand advertising expenditures *after* launch shape the effect of design innovativeness on product sales over time?" (p. 99).	
Rubera and Droge (2013)	Sales; Tobin's q	Design innovation;	Branding strategy		1."What is the impact of design innovation versus technology	Consumer electronics industry; *n* =

		Technology innovation			innovation on firm performance?" (p. 448); 2."What is the impact of their potentially synergistic interaction?" (p. 448); 3."How one key strategic marketing decision [i.e., branding strategy] influences the degree of impact of technology versus design innovations on consumer versus	1168 firm–year

					investor response" (p. 449).	
Talke et al. (2009)	Sales	Design newness; Technical newness			1."Why a design perspective is essential when assessing product innovativeness" (p. 602); 2. "Whether such a perspective [i.e., design] has an impact on the performance of new products . . ." (p. 602)."	Automobile industry; *n* = 157 cars
	Design–performance studies					

Boyd and Kannan (2018)	Firm value	Third-Party recognition for design excellence	CEO functional experience; Function and form design excellence criteria		"Provide clear and unambiguous insight for researchers and marketers regarding the implications of third-party recognition for design excellence in B2B markets" (p. 2).	B2B, public-traded firms; *n* = 102 firms
Jindal et al. (2016)	Market share	Functional design; Form design; Ergonomic design	Vehicle age generation		1. "How should these dimensions [i.e., form, function, ergonomics] be configured to create a winning product?" (p. 72); 2. "Can design help older products	U.S. light vehicle industry; *n* = 937 vehicles models (over six years)

					hold their share, and if so, is there a differential impact among the subdimensions?" (p. 73).	
Candi (2016)	Market performance	Design emphasis; Design resources		Design excellence	"How design resources (designers), design emphasis (emphasis on aesthetics and experience) and the outcomes of design (design excellence) jointly contribute to market performance in	Technology-based service firms; *n* = 176 firms

					technology-based firms engaged in service innovation" (p. 33).	
Czarnitzki and Thorwarth (2012)	Innovation performance	Design in-house			"Whether design activities conducted in house differ in their contribution to new product sales from externally acquired design" (p. 878). "	All industries; *n* = 1511 firms
Chiva and Alegre (2009)	Market performance	Design investment		Design management	"How design investment impacts firm performance and how this relationship is mediated by design	Ceramic tile industry; *n* = 182 firms

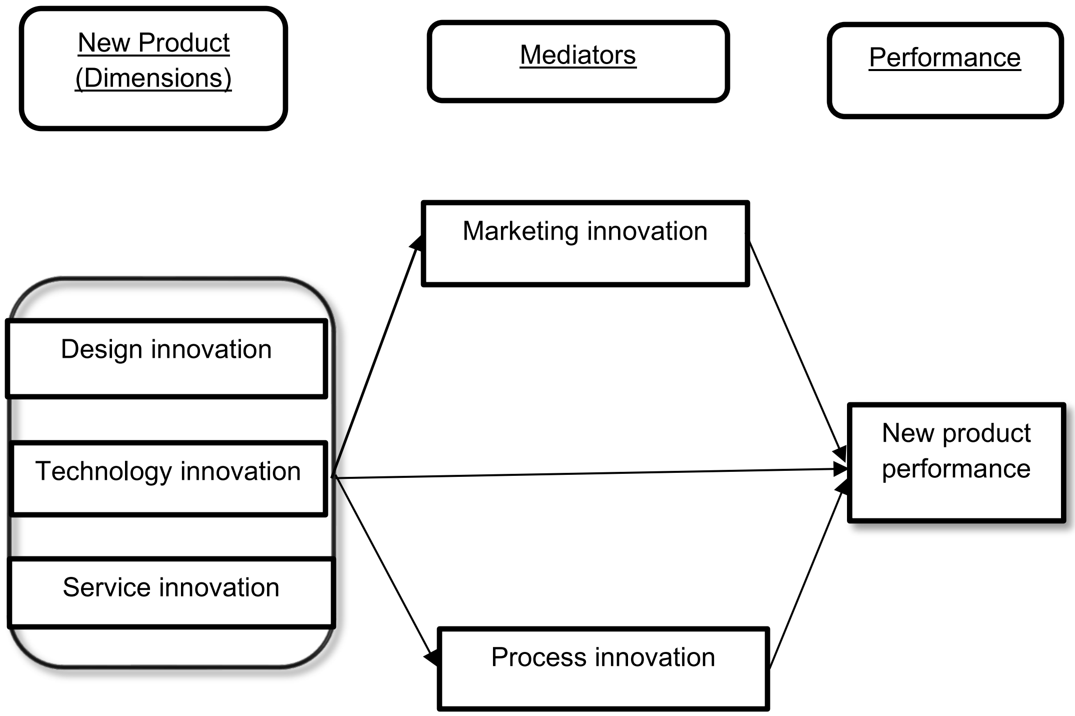
					management skills" (p. 425). "	
Hertenstein et al. (2005)	Firm performance	Design effectiveness			"Examines the relationship between industrial design and company financial performance in order to assess industrial design's contribution to this performance" (p. 5).	Nine manufacturing industries; public-traded companies; *n* = 172 firms
Gemser and Leenders (2001)	Firm performance	Design intensity			"How industrial design affects the performance of companies?" (p. 29).	Home furniture (*n* = 23 firms) and precision

						instruments industries (*n* = 23 firms)

Chapter 3

Study 1. Theory Development

The theoretical framework is built upon the literature on design, service, marketing, and process innovation. First, I propose that a new product should include three types of innovation—design, technology, and service innovation, and they all contribute to the new product performance. Second, I propose examining marketing innovation and process innovation as two mediators in this new product (encompassing design, technology, and service innovation)–performance relationship. I argue that marketing and process innovation could be driven by firms' introduction of new products (e.g., Damanpour & Gopalakrishnan, 2001; Pisano, 1997; Ramirez et al., 2018; Reichstein & Salter, 2006). Marketing and process innovation mainly play the roles of "exploiting" the values of new products and producing the new products effectively and efficiently (e.g., Bartoloni & Baussola, 2016; Damanpour & Gopalakrishnan, 2001; Pisano, 1997; Ramirez et al., 2018; Reichstein & Salter, 2006).



Quick definitions:

- Design innovation: significant changes in aesthetics
- Technology innovation: significant changes in technology
- Service innovation: significant changes in service
- Marketing innovation: significant changes in promotion, pricing, or placement
- Process innovation: significant changes in production process

Figure 1. Study 1 Theoretical framework.

3.1. Design Innovation, Technology Innovation, and Service Innovation

Product design could communicate and send cues to customers about the utility and function of the product so that it helps customers understand a product's utility (or function) better (Creusen & Schoormans, 2005; Homburg, Schwemmle, & Kuehnl, 2015; Kreuzbauer & Malter, 2005; Micheli & Gemser, 2016; Mugge & Schoormans, 2012; Rubera & Droge, 2013). For example, a larger hairdryer implies that it is more powerful than a smaller one (Creusen & Schoormans, 2005). In a similar vein, design innovation may facilitate customers' understanding of the technology change of the product through design (Rindova & Petkova, 2007; Rubera & Droge, 2013).

In addition, innovative product design contributes to performance (e.g., sales) since it delivers value to customers (Micheli & Gemser, 2016; Rubera & Droge, 2013). The value of product design lies in multiple dimensions, such as its aesthetics, ergonomics, and symbolism which meet customers' needs of hedonism, the comfort of use, and self-expression (Homburg et al., 2015; Jindal et al., 2016). Consumers capture the value from a product as it delivers the functionality (or utility) and appeals to consumers' emotions and feelings, creates a smooth and pleasant experience, and allows customers to express their own identities and values through consuming this product (Homburg et al., 2015; Jindal et al., 2016; McCracken, 1986).

Furthermore, innovative product design enables a firm to make a product offering different from its competitors and, in turn, increase its competitive advantage (e.g., Micheli & Gemser, 2016; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009).

Design innovation is a strategic decision a firm makes to differentiate products and to increase its performance. Design innovation sends a positive signal of product quality and performance, which can be perceived by customers and eventually captured by the market performance (Micheli & Gemser, 2016; Mugge & Schoormans, 2012). Consumers respond to innovative design also because it excites and motivates consumers to search for product information and try the new product (Rubera & Droge, 2013; Talke et al., 2009).

Product development is shifting to a perspective that has integrated function and form (in other words, technology, and design), and this perspective is imperative for firm strategy and business success (Luchs & Swan, 2011). A new product consists of two basic elements—technology innovation and design innovation (e.g., Rubera & Droge, 2013). Technology innovation is the significant change in a product's functionality, and design innovation is the significant change in a product's aesthetics (e.g., Dan et al., 2018; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009). Examining innovative products, researchers have considered design innovation and technology innovation as two distinct yet important innovation elements and have found that they both contribute to firm performance (e.g., Dan et al., 2018; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009). Following most of the quantitative studies of design innovation, this study also examines design as well as technology innovation.

Hypothesis 1. Design innovation contributes to new product performance.

Hypothesis 2. Technology innovation contributes to new product performance.

Moreover, this study proposes that service innovation is a third innovation element crucial to the new product-related study. In the manufacturing industries, services create value by complementing product offerings that differentiate firms from their competitors (Gebauer & Friedli, 2005; Santamaría, et al., 2012; Vandermerwe & Rada, 1988). New products and services may spotlight the offering differentiation (Gebauer & Friedli, 2005). Offering "bundles," including products and services, is a customer-centered approach that enhances firms' competitive advantages (Gebauer & Friedli, 2005; Vandermerwe & Rada, 1988). Santamaria et al. (2012) summed three ways for firms to offer services (for manufactured products).

The first approach is "to offer the manufactured products along with closely related services in a single package, aiming to make them more attractive than those of their competitors" (Santamaría et al., 2012, p. 146). Examples can be financial services, maintenance services, and leasing services packaged with the products (Santamaría et al., 2012). The second approach is "to offer the consumer not the product itself, but rather the goal that the purchase of the manufactured product will ultimately fulfil, the functionality it will provide" (Santamaría et al., 2012, p. 146). Examples can be the cloud computing services and system services offered by the manufacturers (Santamaría et al., 2012). Another approach "involves improving the acceptability of a product by overcoming obstacles to its adoption or use" (Santamaría et al., 2012, p. 146). This approach involves understanding customers' real needs (which could be beyond the actual products they purchase) (Santamaría et al., 2012).

Service complements new products and is even becoming a significant part of the new product. For example, when three manufacturers (Trek, Raleigh, and Giant) developed a new bike called Coasting bike, they not only innovated the bike in its aesthetics and function (Brown, 2008). They also created a website that mapped out the safe and cool bike paths to facilitate users' biking experience (Brown, 2008). The Coasting bike is an excellent case showing how design, technology, and service innovation are integrated into new product development.

In addition to the typical service offered in the manufacturing industry, such as installation, training, and after-sales services, data network, artificial intelligence, and other capabilities and technologies are also increasingly enhancing product and user experience (Raff, Wentzel, & Obwegeser, 2020; Santamaría et al., 2012; Verganti, Vendraminelli, & Iansiti, 2020). As design thinking and a user-centric mindset are being promoted in product design (Micheli, Wilner, Bhatti, Mura, & Beverland, 2018), the understanding of product design is moving to adopt a holistic view that may motivate the innovation in a product's functionality, aesthetics, as well as service to satisfy customers (Micheli et al., 2018).

Defining service innovation as "a new service" is probably one of the standard interpretations from the literature (Witell et al., 2016, p. 2868). The benefits of service innovation might be arguable since "even if a new service creates significant benefits for customers, the service might not generate revenue to the developer" (Witell et al., 2016, p. 2865). The importance of service innovation is getting attention, though. New services may contribute to sales in bundles with new products. Firms can also lease their services to make profits.

For example, Tetra Pak (the firm producing aluminum-lined juice cartoons) leased out its software which allows other firms to operate the same packaging technology (Santamaría et al., 2012). In business-to-business marketing, if a firm fails to bundle the professional service (e.g., consulting and training) with the new product, it may experience failure in product launch. It is the case with EMI Corporation, which failed to offer professional services meant to help the hospital buyers understand its new CAT Scanners (Visnjic, Wiengarten, & Neely, 2016).

Overall, service innovation studies are sparse, especially on the performance implication of service innovation. However, scholars have attempted to understand service innovation's scope, phenomenon, and definition (Toivonen & Tuominen, 2009; Witell et al., 2016) and the antecedents of service innovation in manufacturing industry (Santamaría et al., 2012). From a product differentiation perspective, this study argues that service innovation should be considered a new product's third innovation element (in addition to technology and design innovation), and service innovation should contribute to new product performance.

Hypothesis 3. Service innovation contributes to new product performance.

3.2. Marketing Innovation as A Mediator

The capabilities perspective posits that capabilities (or competencies) allow some firms to perform better than others by creating value effectively (Danneels, 2002; Grant, 1996; Krasnikov & Jayachandran, 2008; Teece, Pisano, & Shuen, 1997). Marketing capabilities can be broadly defined as the capabilities in knowledge of customer needs and preferences, pricing, channel management, selling, and marketing communication (Danneels, 2002; Vorhies & Morgan, 2005). In the context of product development, marketing capabilities also facilitate the information exchange between customers and firms for product development and commercialization (Danneels, 2002; Vorhies & Morgan, 2005).

Danneels (2002) established the framework of "second-order competencies [interchangeable with capabilities]" and state that second-order competencies point to "the ability to identify, evaluate, and incorporate new technological and/or customer competences into the firm, i.e., a competence at explorative learning by exploring new markets or exploring new technology" (p. 1112), while the first-order competencies refer to a firm's existing customer and technological competences. In particular, second-order competences are "the ability to build new first-order competences" (Danneels, 2002, p. 1114). In this sense, marketing innovation (i.e., novel marketing methods) could be seen as a higher level of marketing capabilities and a "second-order competence" of marketing (Danneels, 2002; Grimpe et al., 2017).

Grimpe et al. (2017) pointed out that a stream of literature considers marketing "as a mechanism for exploiting technologically novel products commercially . . . " (p. 362).

Since new products need to be brought to market and customers, novel marketing methods are desired to fully exploit the potential values from the new products (Bartoloni & Baussola, 2016; King et al., 2008; Ramirez et al., 2018). This study thus also focuses on the aspect of marketing innovation that exploits the value of the new product. Hereby, I define marketing innovation as the new methods in pricing, placement (or distribution), or promotion activities. It slightly deviates from the perspective of the OECD (2005), which defines marketing innovation as "the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing" (p. 49). The main reason is this study sees design innovation as an element of a new product rather than a marketing activity.

Examples of pricing innovation include flexible pricing methods used in digital supermarkets and pre-paid and flat-rate pricing methods in the telecommunication industry (Grimpe et al., 2017). Examples of placement (or distribution) innovation include—Tesla Motors' own innovative distribution method (i.e., using the distribution methods of showrooms or own stores rather than the regular car dealerships) and book and news publishers selling their content via digital platforms (Grimpe et al., 2017; Mangram, 2012). Noteworthy, introducing a new product may spur new marketing method(s) used to bring the new product to the market and customers. For example, when the Coasting bike was developed, a new brand was also designed to position it as a lifestyle brand ("a way to enjoy life") (Brown, 2008, p. 90). Developing a new product (concerning design, technology, and service innovation) will likely push firms to introduce innovative marketing methods (i.e., innovative pricing, placement, or promotion methods).

Marketing innovation is found to be positively related to profitability, competitive advantage, and new product performance (Bhaskaran, 2006; Grimpe et al., 2017; Naidoo, 2010). Nevertheless, few studies have examined the relationship between new products and marketing innovation. Ramirez et al. (2018) concluded that technology innovation leads to marketing innovation. Grimpe et al. (2017) showed a dis-synergistic effect between technology innovation and innovative marketing activities, given resource constraints. Their study also indicates that some managers think having many different innovation activities may not benefit the firms' brand (Grimpe et al., 2017). The interplay between marketing innovation and technology, design, and service innovation is worth exploring. Synthesizing the existing literature, I argue that introducing new products (captured by design, technology, and service innovation) stimulates marketing innovation, which, in turn, contributes to new product performance. In other words, design, technology, and service innovation have indirect effects on new product performance via marketing innovation.

As researchers seek to understand marketing innovation, some perceive marketing innovation as a complement or support to new products which mainly achieves the potential values and benefits from the new products (e.g., Bartoloni & Baussola, 2016; Ramirez et al., 2018). Others adopt different lenses. For example, Naidoo (2010) argues that marketing innovation differentiates firms' combination of resources and makes them hard for competitors to imitate. Grimpe et al. (2017) perceive marketing innovation “as a source of new products itself” (p. 360). Following the literature stream that mainly views marketing innovation as a support to new products (e.g., Bartoloni & Baussola, 2016; Ramirez et al., 2018), I examine marketing innovation through its role in “exploiting” new products. This perspective is in line with the understanding of marketing capability, which is mainly about customer-linking and accountable for bringing new product offerings to the market and customers effectively (Day, 1994; Krasnikov & Jayachandran, 2008).

Hypothesis 4. Marketing innovation mediates the relationship between design, technology, and service innovation and new product performance, respectively.

3.3. Process Innovation as A Mediator

Process innovation is “the introduction of new or significantly improved production, supply chain, and administrative processes” (Piening & Salge, 2015, p. 80). This paper examines process innovation from a dynamic capabilities perspective. Dynamic capabilities refer to a firm’s “ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments” (Teece et al., 1997, p. 516). This perspective concurs with the scholars who began to adopt the lenses of dynamic capabilities in their examination of process innovation (Macher & Mowery, 2009; Piening & Salge, 2015; Woiceshyn & Daellenbach, 2005). Dynamic capabilities can be seen as higher-order capabilities that allow firms to reconfigure their capabilities, including manufacturing and logistics capabilities, to increase efficiencies and effectiveness and eventually contribute to performance (Helfat & Winter, 2011; Piening & Salge, 2015; Teece et al., 1997). In the context of product development, dynamic capabilities also support managing complicated relationships with suppliers to ensure timely production and delivery (Helfat & Winter, 2011).

The benefits of process innovation mainly hinge on reducing the cost, time of production (or manufacturing), time to market and improving overall product quality, effectiveness, efficiency, productivity, and sales (Baer & Frese, 2003; He & Wong, 2004; Klomp & Van Leeuwen, 2001; Lee et al., 2017; Piening & Salge, 2015; Pisano, 1997). Efficiency and cost-reduction in production as well as supply chain technologies allow firms to optimize the production process and thus pass along the values to end customers (Dehning, Richardson, & Zmud, 2007; He & Wong, 2004; Piening & Salge, 2015). Manufacturing capability (which involves converting various inputs into desired outputs) is shown to lead to market performance as it satisfies and delivers values to customers (Lee et al., 2017; Li, 2005). Therefore, this study proposes that process innovation may contribute to new product performance since process innovation facilitates the efficiency and effectiveness of the production process, thus delivering value to customers through the enhancement of efficiency, effectiveness, and quality of the new products (Baer & Frese, 2003; He & Wong, 2004; Klomp & Van Leeuwen, 2001; Lee et al., 2017; Piening & Salge, 2015).

Some might think fixed product design (large-scale production) could be associated with process innovation since one aspect of process innovation corresponds to cost-efficiency strategies (Reichstein & Salter, 2006). Some may also think process innovation is less likely to occur with product differentiation (Reichstein & Salter, 2006). Yet, a few empirical studies provide evidence that technology innovation is associated with process innovation (Damanpour & Gopalakrishnan, 2001; Pisano, 1997; Reichstein & Salter, 2006) where process innovation is viewed or found as a result of technology innovation (Damanpour & Gopalakrishnan, 2001; Pisano, 1997; Reichstein & Salter, 2006). Piening and Salge (2015) also found that process innovation has a mediating role in the relationship between the breadth of innovation activities (including R&D and design-related innovation activities) and financial performance.

Developing a new product (concerning design, technology, and service innovation) will likely call for changes in the manufacturing process, supplier management and technologies, or related supports. For instance, designing a thinner laptop may demand different materials or hardware for the laptop and subsequently motivate the change in the production and support process pertinent to the production of this new product. The production process is the intermediate stage responsible for manufacturing new products that will eventually be brought to the market. In this sense, developments of new products (concerning design, technology, and service innovation) may stimulate changes in the production process, which may, in turn, lead to new product performance.

In addition, although services are mostly intangible in nature (Santamaría et al., 2012), firms still need the process to produce services. Services production may require certain investments such as professional or part-time workers, knowledge expertise, and

IT supports (Miles, 1993; Santamaría et al., 2012).. A new service may bring changes in firms' collaboration with external parties, including suppliers and the production system built for this service. Service innovation could be closely related to process innovation. For example, a new IT-enabled service may promote a new system or process which is established upon IT operations (Santamaría et al., 2012).

Hypothesis 5. Process innovation mediates the relationship between design, technology, and service innovation and new product performance, respectively.

Chapter 4

Study 1. Research Data and Method

4.1. Data and Sample

This study draws on data from the *Survey of Innovation and Business Strategies (SIBS)* 2017 and the *Business Registry (BR)*, which are collected by Statistics Canada. The SIBS collects information on Canadian firms' innovation, business strategies, and practices. The SIBS follows the Oslo Manual and is comparable to the *Community Innovation Survey (CIS)*. The CIS has been adopted by European member countries and other countries such as South Korea and Japan, receiving wide acknowledgment and recognition from business and innovation scholars (e.g., Crescenzi & Gagliardi, 2018; Czarnitzki & Thorwarth, 2012; Grimpe et al., 2017; Hashi & Stojčić, 2013; Lee et al., 2017; Santamaría et al., 2012). Respondents of this survey usually include CEOs and department heads from the surveyed enterprises (Grimpe et al., 2017). This study has drawn a sample of 2768 manufacturing firms from the SIBS 2017.

The SIBS survey data were "collected through an electronic questionnaire (EQ), with non-response follow-up and failed edit follow-up for priority questions" (Statistics Canada, 2019, Data sources and methodology section). Enterprises' responses to the SIBS survey are mandatory (Statistics Canada, 2019).

As for sampling method, the survey first required "a census of all large enterprises [with at least 20 employees and $250,000 in revenues] within the NAICS 14 sectors"

(Statistics Canada, 2019, Data sources and methodology section). A stratification sampling method was used based upon "NAICS Canada 2012, region and three size classes [small/medium/large firms] based on number of employees per enterprise" (Statistics Canada, 2019, Data sources and methodology section).

Statistics Canada (2019) states that "non-sampling errors are minimized through careful design of the survey questionnaire and verification of the survey data" (Data accuracy section). In addition, according to Statistics Canada (2019), "non-response is addressed through survey design, respondent follow-up, reweighting, and verification and validation of microdata"; and the "response rate at the estimation phase is 77.4%" (Data accuracy section). Statistics Canada uses imputation to treat "item non-responses" (Statistics Canada, 2019, Data sources and methodology section). Imputation rules are automated using BANFF (STC proprietorial software) (Statistics Canada, 2019). This method uses nearest neighbor rules (Statistics Canada, 2019). Specifically, the nearest neighbor rule finds, "for each record requiring item imputation, its most similar valid record thereby allowing the imputed recipient record to pass the specified imputation edits and post edits rules" (Statistics Canada, 2019, Data sources and methodology section). And the similar records are "found by taking into account other variables that are correlated with the missing values via the customized imputation classes and matching variables (if required) for each item (variable) to be imputed" (Statistics Canada, 2019, Data sources and methodology section).

4.2. Variable Description

4.2.1. Dependent variables. New product performance takes the logarithmic form of the percentage of sales generated by new products or new services which occurred during the year of 2015 to 2017 (Czarnitzki & Thorwarth, 2012; Grimpe et al., 2017). The new products and services can be new to the market or new to the firm. This performance measure is designed based upon OECD's Oslo Manual. This measure has been widely used by innovation and business literature to capture new product and innovation performance and as an outcome variable (e.g., Czarnitzki & Thorwarth, 2012; Grimpe et al., 2017; Hashi & Stojčić, 2013; Lee et al., 2017). Following the literature stream, my study also uses this measure to examine new product performance.

4.2.2. Independent variables. Design innovation is a binary variable indicating if a firm has introduced "significant changes to the aesthetic design or packaging . . ." between 2015 to 2017. **Technology innovation** is a binary variable indicating if a firm has introduced "new or significantly improved goods" (excluding those only changed aesthetics) between 2015 to 2017. **Service innovation** is a binary variable indicating if a firm has introduced "new or significantly improved services" between 2015 to 2017. **Marketing innovation** is a binary variable indicating if a firm has introduced new or significantly different methods for promotion, placement, or pricing between 2015 and 2017. **Process innovation** is a binary variable indicating if a firm has introduced "a new or significantly improved production process, distribution method or support activity" for its products or services between 2015 to 2017.

4.2.3. Control variables. Organization innovation is a binary variable indicating if a firm has introduced "a new organizational method in business practices (including knowledge management), workplace organization or external relations that has not been previously used by this business" between 2015 to 2017. Since organization innovation is related to a firm's overall knowledge management and business practice, it is used as a control variable to capture its potential influence on the performance variable. **Firm size** is a logarithmic form of a firm's average number of employees from 2015 to 2017. This variable is used to capture the "economies of scale and scope" (e.g., Czarnitzki & Thorwarth, 2012, p. 883). **Firm age**, a logarithmic form of a firm's age, is used to capture a firm's reputation and experience (e.g., Czarnitzki & Thorwarth, 2012). **Industry dummies** are constructed based on three-digit North American Industry Classification Systems (NAICS). Twenty-one industry sectoral dummies based on the three-digit NAICS codes are included to capture the unobserved industry variance (see Table A in Appendix A).

4.3. Method

This study attempts to examine the impact of design innovation, technology innovation, and service innovation on new product performance. This study also considers marketing innovation and process innovation as potential mediators in the new product (including design, technology, and service innovation)–performance relationship. Path analysis should be used to assess the potential mediating relationships. This study conducted the generalized structural equation modeling (GSEM) method to estimate the path coefficients since the potential mediators in this study (i.e., marketing innovation and process innovation) are of binary nature.

Using SEM to examine binary mediators might induce biased results (Hillebrand, 2018; Iacobucci, 2012). GSEM is thus applied since GSEM provides consistent and efficient model estimates that accommodate all types of data, including binary and continuous variables (Hillebrand, 2018; Kijek & Kijek, 2019). GSEM used in this study was set to treat the outcome variable (i.e., new product performance) as a left-censored (at the value of zero) continuous variable with Gaussian distribution and the mediators (i.e., marketing innovation and process innovation) as binary variables with Bernoulli distribution.

Moreover, a non-parametric bootstrapping method with 1000 replications is used to estimate the indirect effect via the mediators (Hillebrand, 2018; Zhao, Lynch Jr, & Chen, 2010). A bootstrapping test is recommended as it does not assume sampling distribution and is more powerful than other methods (Zhao et al., 2010). In a SEM model, the indirect effect via a mediator is usually estimated by multiplying the path coefficients from the outcome variable and the mediator (e.g., Zhao et al., 2010). However, since this study's outcome variable and mediators have different sampling distributions, meaning Gaussian and Bernoulli distribution, respectively, this method may introduce biases. Thus, the bootstrapping method should be implemented. The bootstrapping test repeatedly resampled the original sample 1000 times and then took the means of the indirect effects from all replicates (Hayes, 2009; Zhao et al., 2010).

Chapter 5

Study 1. Results

5.1. Descriptive Statistics

Table 2 shows the descriptive statistics of the variables. It gives an overview of the latest innovation activities (from 2015 to 2017) in Canadian manufacturing industries (*n* = 2768). Among all innovation activities, process innovation has the highest occurrence (mean = 0.664), followed by organization innovation (mean = 0.645) and technology innovation (mean = 0.534). The occurrence of marketing innovation (mean = 0.493) is lower than that of technology innovation and higher than that of service innovation (mean = 0.240) and design innovation (mean = 0.199).

Technology innovation used to be the most crucial innovation activity, and the rate of technology innovation adoption is usually higher than the other innovations (e.g., Santamaría et al., 2012). Yet the data from Canadian manufacturing firms presents a different pattern. Technology innovation has lower introductions than process and organization innovation from Canadian data. This observation may reflect a shifting focus on the type of innovation activity. In addition, over half of the manufacturing firms have introduced process and technology innovation, and nearly half have introduced marketing innovation, striking the importance of these innovation activities. Almost one in five firms has introduced design and service innovation. Design and service innovation are getting more significance in the recent years.

Table 3 shows the correlations of independent and control variables. Individual variance inflation factors (VIF) and mean VIF are all very low (< 2), indicating no multicollinearity problems in the model. As for the correlations between innovation activities, organization innovation and process innovation have a relatively higher correlation (0.45) than the others.

Table 2

Descriptive Statistics

	Mean	**Std. Dev.**
Design innovation	0.199	0.399
Technology innovation	0.534	0.499
Service innovation	0.240	0.427
Marketing innovation	0.493	0.500
Process innovation	0.664	0.472
Organization innovation	0.645	0.479
Firm size (log)	4.515	1.163
Firm age (log)	2.959	0.559
New product performance (log)	1.278	1.573

Table 3

Correlation Table

		1	2	3	4	5	6	7	8	VIF
1	Design innovation									1.28
2	Technology innovation	0.28								1.36
3	Service innovation	0.22	0.28							1.22
4	Marketing innovation	0.34	0.31	0.28						1.35
5	Process innovation	0.23	0.38	0.26	0.30					1.43
6	Organization innovation	0.24	0.28	0.25	0.36	0.45				1.40
7	Firm size (log)	0.03	0.12	-0.03	0.03	0.10	0.10			1.11
8	Firm age (log)	-0.05	-0.01	0.00	0.01	-0.03	-0.04	0.11		1.05
9	Industry dummies	-0.12	0.10	0.11	0.03	0.05	0.08	-0.04	0.07	
									Mean VIF	**1.35**

Note. Industry dummies are calculated in mean VIF (not presented).

5.2. Estimation Results

Table 4 below shows all direct effects from GSEM analysis. It displays the direct effects of design innovation, technology innovation, service innovation, marketing innovation, and process innovation on new product performance, respectively. Table 5 also shows the effects of design, technology, and service innovation on two mediators—marketing and process innovation.

The direct effect of design innovation on new product performance in Table 4 shows that design innovation impacts new product performance directly (β = 0.359 at $p < .01$). Technology innovation is positively related to new product performance as well (β = 3.908 at $p < .001$). Service innovation is also positively related to new product performance (β = 1.324 at $p < .001$). The three types of innovation (i.e., design, technology, and service innovation) that usually occur from new product development all have significant and positive relationships with new product performance. Thus, H1, H2, and H3 are all accepted. As of control variables, organization innovation is significantly and positively related to new product performance (β = 0.539 at $p < .001$). Firm size and firm age are not significantly related to new product performance.

Table 4

Direct Effects on New Product Performance

	New Product Performance
Independent	
design innovation	0.359**
technology innovation	3.908***
service innovation	1.324***
marketing innovation	0.423***
process innovation	0.378**
Control	
firm size	-0.053
firm age	0.033
organization innovation	0.539***
intercept	-3.578 ***
Obs	2768

Notes. *p < 0.05; **p < 0.01; ***p < 0.001.

Industry dummies are included (not presented).

The indirect effects are calculated and displayed in Table 5 to examine the mediation of the effect of design, technology, and service innovation through marketing innovation and process innovation, respectively. Design innovation has a significant and positive indirect effect on new product performance through marketing innovation ($\beta = 0.599$ at $p < .001$). Technology innovation has a significant and positive indirect effect on new product performance through marketing innovation ($\beta = 0.300$ at $p < .01$). Service innovation has a significant and positive indirect effect on new product performance through marketing innovation ($\beta = 0.329$ at $p < .01$). The results show that H4 is accepted. Moreover, the indirect effects of design, technology, and service innovation on new product performance via process innovation are all positive and significant ($\beta = 0.262$ at $p < .05$ for design innovation; $\beta = 0.486$ at $p < .01$ for technology innovation; $\beta = 0.332$ at $p < .05$ for service innovation). Thus, H5 is also accepted. Noteworthy, the indirect effect of design innovation on new product performance via marketing innovation ($\beta = 0.599$) is greater than its direct effect (β = 0. 359) as well as the indirect effect via process innovation ($\beta = 0.262$) on performance outcome. It may imply the important role of marketing innovation in converting design innovation to new product performance.

Table 5

Post-estimated Indirect and Total Effects on New Product Performance

	New Product Performance	
	Indirect	Total
(1) via marketing innovation		
design innovation	0.599***	0.959***
technology innovation	0.300**	4.208***
service innovation	0.329**	1.653***
(2) via process innovation		
design innovation	0.262*	0.621***
technology innovation	0.486**	4.393***
service innovation	0.332*	1.656***

Note. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

To test the **robustness** of the results, the sample was divided into high-tech and low-tech industry groups based on the R&D intensity classified by OECD (2011). Because the relationship between the innovation activities and new product performance might be sensitive to the R&D intensity of the industries. The complexities and features of technology, design and service innovation might be different in high-tech and low-tech industry groups. The result patterns of the sub-samples are the same as the full sample.

Chapter 6

Study 1. Theoretical Contributions and Managerial Implications

The study contributes to the design innovation literature as well as new product development literature by jointly examining the relationship between design, technology, service innovation, marketing and process innovation, and new product performance in the context of Canadian manufacturing firms. Consistent with the extant design innovation literature, this study considers design and technology innovation as the two main innovative elements of a new product as it explores the relationship between design innovation and performance. In addition, this study also considers service innovation as another new product dimension. This perspective is inspired by the design thinking literature (Micheli et al., 2018) that promotes a user-centric mentality in product design and takes into account that the service component (e.g., artificial intelligence) is getting more significant in new product development.

Moreover, the study argues that design, technology, and service innovation may drive marketing and process innovation and subsequently result in better new product performance. This perspective is motivated by the literature that supports a technology innovation–marketing innovation pattern (suggesting that technology innovation leads to marketing innovation) (e.g., Ramirez et al., 2018)) and technology innovation–process innovation pattern (suggesting that technology innovation leads to process innovation) (e.g., Damanpour & Gopalakrishnan, 2001). In other words, design, technology, and service innovation impact new product performance indirectly via marketing and process innovation. Marketing innovation and process innovation capture the innovation activities introduced to “exploit” and produce a new product. This study thus delineates the interplays of design, technology, and service innovation and marketing and process innovation in a new product–performance framework. While the existing design innovation literature has examined variables such as expert and media recognition (Micheli & Gemser, 2016), adherence to a design tradition (Micheli & Gemser, 2016), brand strength and brand advertising expenditure (Rubera, 2015), and branding strategy (Rubera & Droge, 2013) as a mediator or moderators in a design innovation–performance model, no studies have examined marketing innovation and process innovation in their roles to support and manufacture new products that consist of design innovation as well as technology and service innovation. The holistic view investigating the relationships between design, technology, and service innovation and marketing and process innovation and how they jointly contribute to new product performance constitutes the key contribution of this study.

Results of the study show that all hypothetical relationships are accepted. Introducing design and technology (as well as service) innovation increases the likelihood of introducing marketing and process innovation, enhancing the new product performance. Marketing and process innovation partially mediated the relationship between design, technology, service innovation, and new product performance. Moreover, comparing all direct and indirect effects, the study notes that the indirect effect of design innovation via marketing innovation is higher than the other indirect effects. The finding shows an intriguing relationship between design innovation and marketing innovation, implying that innovative marketing methods (in promotion, pricing, or delivery) are critical to "exploit" the value and benefits of innovative design (Bartoloni & Baussola, 2016; Grimpe et al., 2017; King et al., 2008). This finding further advances the understanding of the interplay between innovative product design and marketing methods. Previous studies have shown the mediating role of "expert and media recognition" (Micheli & Gemser, 2016) in design innovation–firm performance and have found branding-related variables as moderators in this relationship (Rubera, 2015; Rubera & Droge, 2013). This study demonstrates that marketing innovation is crucial as the innovation activity to "exploit" the value of a new product (particularly concerning design innovation) and enhance the new product performance.

From a practical perspective, this study first shows that design innovation (as well as technology and service innovation) contributes to new product performance. Canadian managers may start to realize the value of product design and consider investing in new product design. Managers need to consider the value that can be delivered to customers through good product design—whether the new product design better communicates the product's utility, pleases customers, makes the products easy to use or allows customers to express themselves better through using the product (Homburg et al., 2015; Jindal et al., 2016; Micheli & Gemser, 2016; Mugge & Schoormans, 2012). In addition, having in-house design capacity is imperative as it is found to have significant influence on the new product performance (Czarnitzki & Thorwarth, 2012).

Second, innovative marketing methods are important to exploit the value of new products, especially new design. This suggests that managers need to build up their marketing capabilities which would allow them to develop innovative and compatible strategies and tactics in promotion, pricing, or delivery to facilitate the launching of new products. Marketing innovation is generally more intensive in computers and electrical manufacturing sector, food and beverages sector, printing sector, and plastics and furniture sector, among all Canadian manufacturing industry sectors (Persaud, Wang, & Schillo, 2021). These are also the sectors that are design-intensive.

Lastly, the development of new products begets process innovation, which also impacts performance. Process innovation could invovle “changes in production process” (e.g., “modification to cathode processing techniques” and“introduction of bulk packaging of sleeved products”), “new management practices” (e.g., adopting lean production and changes in assembly mode), and “introduction of new machinery and equipment” (see Reichstein & Salter, 2006, p. 14). Since design, technology, and service innovation all generate process innovation, the new product development team (which may comprise engineering designers, industrial designers, and marketers) needs to work closely with plants, manufacturers, and suppliers for efficient production.

Chapter 7

Study 1. Conclusions and Directions for Future research

This study takes a holistic view examining how design innovation, technology innovation, and service innovation drive new product performance directly and indirectly via marketing innovation and process innovation. This study considers design, technology, and service innovation as the three main innovation elements that constitute a new product and explores their effects on new product performance via marketing innovation and process innovation. Marketing and process innovation are spurred by innovative products (encompassing design, technology, and service innovation) since marketing is the function of "exploiting" the potential values and benefits of new products, and process concerns how new products are produced. The holistic view that integrates a new product–performance relationship and the intermediate roles of marketing innovation and process innovation underlines the main contribution of this study. The research findings show that design, technology, and service innovation contribute to new product performance directly and indirectly via marketing and process innovation. The indirect effect of design innovation on performance via marketing innovation is high, suggesting an important role of marketing innovation in converting innovative product design to performance.

One limitation of the study lies in the cross-sectional nature of the survey answers. The SIBS is designed to capture firms' innovation activities for three years, and thus a panel study cannot be performed with one wave of the survey. Future research could consider collecting three waves of the SIBS to conduct a longitudinal study which may address this limitation. Another limitation is the potential feedback effects of marketing and process innovation on design, technology, and service innovation. Although the dependent variable used in this study has been well accepted as an innovation or new product performance measure, the questions used to compose innovation variables (i.e., design, technology, service, marketing, and process innovation) only indicate these innovation activities were introduced from 2015 to 2017. The possibility of the recursive relationships between marketing and process innovation and design, technology, and service innovation is not ruled out. This weakness thus opens the possibilities for future research to consider and model the potentially recursive relationships between these innovation activities.

Another direction for future research is to explore the dynamics between design, technology, and service innovation and marketing innovation since marketing innovation is found to be an important mediator in the new product–performance model. Marketing innovation in this study is operationalized based upon three types of innovation activities—promotion, pricing, and placement innovation—each one being a significant topic itself in the field of Marketing. Understanding the interplay between each type of marketing innovation (promotion, pricing, and placement innovation) and design, technology, and service innovation and how they jointly impact performance is a research topic that can be further investigated.

Moreover, future research could consider using data such as design patents (Dan et al., 2018; Lee et al., 2017; Rubera & Droge, 2013) and design innovation investment to measure design innovation activity and to capture the covariance between design innovation and new product performance. It may depend on the availability of such data and the designing of the survey questions. In a similar vein, researchers could also consider using data such as R&D patents and investment, firms' investment in launching new products, and expenditures in marketing innovation to measure technology innovation and marketing innovation. Statistics Canada, the agency that conducts the SIBS, also keeps refining and modifying the questionnaire to reflect the advancement of research findings and interest of innovation and business strategies topics. Lastly, since the SIBS is comparable to the CIS data from European countries, conducting comparative cross-country studies might be another direction for future studies. Some European countries, such as Italy, France, and Sweden, have international reputations for their designers' brands and expertise in design. Cross-region collaboration and exchange of innovation activities might be more frequent across European countries. Interesting findings might be generated through cross-country comparative studies.

Appendix A

Table A

Manufacturing Sectors

Code	Industry Sector
311	Food manufacturing
312	Beverage and tobacco product manufacturing
313	Textile mills
314	Textile product mills
315	Clothing manufacturing
316	Leather and allied product manufacturing
321	Wood product manufacturing
322	Paper manufacturing
323	Printing and related support activities
324	Petroleum and coal product manufacturing
325	Chemical manufacturing
326	Plastics and rubber products manufacturing
327	Non-metallic mineral product manufacturing
331	Primary metal manufacturing
332	Fabricated metal product manufacturing
333	Machinery manufacturing

334	Computer and electronic product manufacturing
335	Electrical equipment, appliance and component manufacturing
336	Transportation equipment manufacturing
337	Furniture and related product manufacturing
339	Miscellaneous manufacturing

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Chapter 8.

Study 2

Examining the Antecedents of Design Activities: Insights from Canadian Manufacturing Industries

The theoretical framework is built upon the literature on design, innovation, and new product development. Incorporating the perspectives of competitive strategies, absorptive capacity, and the RBV, I mainly investigated firms' strategic aspects that lead to design as well as R&D activities. The design and R&D activities discussed in this study are innovation activities defined by the OECD Oslo Manual (2005). The Oslo Manual (2005) states that innovation activities such as R&D and design "actually lead, or are intended to lead, to the implementation of innovations" (p. 18). The Oslo Manual (2005) defines the term "design" as "the form and appearance of products and not their technical specifications or other user or functional characteristics" (p. 96), a definition adopted by this study as well. It is also consistent with the study from Czarnitzki and Thorwarth (2012), who used the same definition as they examined design activities. Moreover, R&D activities correspond to technology innovation since technology innovations "typically stem from scientific discovery and R&D effort" (Grimpe, Sofka, Bhargava, & Chatterjee, 2017, p. 362). In this sense, I investigated the factors that drive firms' design and R&D activities, since they typically lead to the implementation of design and technology innovation (Czarnitzki & Thorwarth, 2012; Grimpe et al., 2017; OECD, 2005).

Very few studies attempted to understand the sources or antecedents of design innovation. The only empirical study, to my knowledge, is from Dan, Spaid, and Noble (2018), who found that environmental variables such as market size and market growth drive design innovation. My paper is mainly interested in looking into the firms' strategic factors that drive design activities.

First, I examined the antecedents of design as well as R&D activities from three aspects: competition and competitor responsiveness, absorptive capacity, and product development resources. Absorptive capacity is captured by two variables: "market sources of information" which are obtained through collaboration with suppliers, customers, consultants, or competitors (Crescenzi & Gagliardi, 2018; Czarnitzki & Thorwarth, 2012; Hashi & Stojčić, 2013; Santamaría, Nieto, & Miles, 2012) and "institutional sources of information" which are mainly obtained through collaboration with universities, governments, or public R&D institutes (Crescenzi & Gagliardi, 2018; Czarnitzki & Thorwarth, 2012; Hashi & Stojčić, 2013; Santamaría et al., 2012). Product development resources are captured by three variables: cross-functional design teaming (as of people factor), design or information control technologies (as of tool factor), and concurrent engineering design (as of process factor). A "people, product, process and tool" framework is summarized by Fixson and Marion (2012), which helps examine the main aspects in new product development.

Moreover, I also examined the differential impacts of these antecedents on design and R&D activities. I attempted to understand the (potentially) different mechanisms underneath firms' decisions to carry out design and R&D activities. Design and R&D activities make critical and complementary inputs of new products. Although they might be simultaneously conducted in the new product development process, the driving forces of design and R&D activities could vary. Thus, I also investigated the impacts of the antecedents on design versus R&D activities. Comparing the impacts may deepen our understanding of how firms' strategies and resources drive design and R&D activities differently.

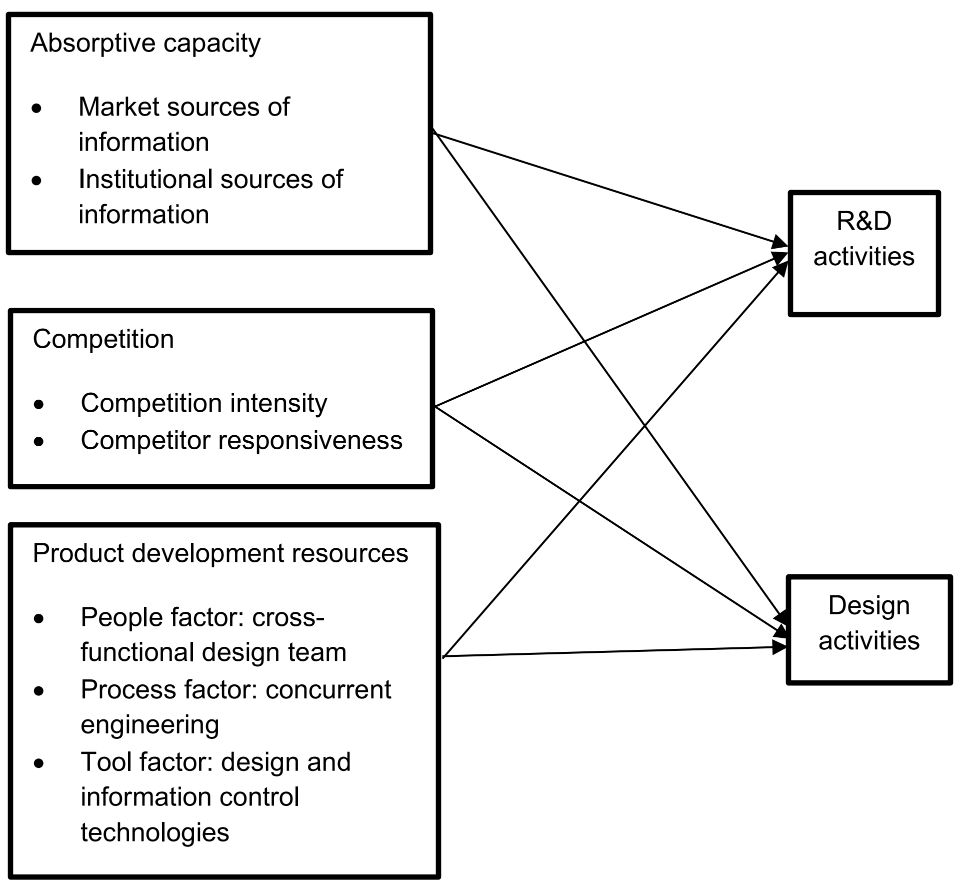

Figure 2. Study 2 Theoretical framework.

Theory Development

8.1. Design Versus R&D Activities

An excellent or innovative design is well perceived, acknowledged and paid by customers (Jindal, Sarangee, Echambadi, & Lee, 2016; Mugge & Dahl, 2013). As "form" and "function" (see Townsend, Montoya, & Calantone, 2011) are gradually getting acknowledgment as the two fundamental elements of a product (e.g., Rubera & Droge, 2013), marketing and innovation scholars begin to explore design innovation and technology innovation as two main innovation and new product development outcomes through examining them in the same setting (e.g., Dan et al., 2018; Rubera, 2015; Rubera & Droge, 2013; Talke, Salomo, Wieringa, & Lutz, 2009).

To distinguish design innovation from technology innovation, scholars define design innovation as the change (or sometimes the "degree of change") only in a product's form or aesthetics (Dan et al., 2018; Micheli & Gemser, 2016; Rubera, 2015; Talke et al., 2009). This concept strikes the distinction between design innovation and technology innovation—that technology innovation points to a product's functionality change whereas design innovation points to a product's form (or aesthetics) change (Dan et al., 2018; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009). A product's aesthetic elements could include "a product's shape, proportion, materials, and color" (Micheli & Gemser, 2016, p. 613). This distinction is consistent with how the OECD Oslo Manual (2005) defines "design" as "the form and appearance of products and not their technical specifications or other user or functional characteristics" (p. 96).

Design and R&D as innovation activities typically result in the introduction of design and technology innovation (Czarnitzki & Thorwarth, 2012; Grimpe et al., 2017; OECD, 2005). Moreover, design and R&D are also considered separate yet complementary activities, making necessary inputs for a new product (Czarnitzki & Thorwarth, 2012). In this context, I examined design and R&D activities in the same setting since a firm may conduct design and R&D activities simultaneously.

8.2. The Impact of Absorptive Capacity on Design Activities and R&D Activities

Absorptive capacity is becoming an important ability that helps researchers understand innovation processes and performance (Cohen & Levinthal, 1990; Martín-de Castro, 2015). Absorptive capacity is defined as "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen & Levinthal, 1990, p. 128). This view of absorptive capacity is mainly an "ability-oriented perspective focusing on the recipient firm's capacity to absorb knowledge from others" (Abecassis-Moedas & Mahmoud-Jouini, 2008, p. 475). Firms that have this capacity are more able to recognize and acquire eternal knowledge that could be initially outside or beyond their boundaries and exploit the external sources of information to their own benefits (Arora & Gambardella, 1994; Crescenzi & Gagliardi, 2018; Martín-de Castro, 2015). In addition, firms that have this capacity are also capable of assimilating and recombining the absorbed knowledge with their internal knowledge to commercial use and innovation development (Cohen & Levinthal, 1990; Crescenzi & Gagliardi, 2018).

Firms could realize absorptive capacity through collaborating with external parties to absorb different external knowledge and information. “Market sources of information” refer to the information and knowledge acquired through collaborating with third parties such as suppliers, customers, consultants, competitors, or commercial labs (Crescenzi & Gagliardi, 2018; Czarnitzki & Thorwarth, 2012; Hashi & Stojčić, 2013; Santamaría et al., 2012). “Institutional sources of information” refer to the information and knowledge acquired through collaborating with third parties such as universities, governments, or public R&D institutes (Crescenzi & Gagliardi, 2018; Czarnitzki & Thorwarth, 2012; Hashi & Stojčić, 2013; Santamaría et al., 2012). These two sources of information could be proxies of firms’ capacities to exploit and realize external knowledge (e.g., Crescenzi & Gagliardi, 2018). Thus, I use “market sources of information” and “institutional sources of information” to capture firms’ absorptive capacity.

The importance of absorptive capacity is getting attention from innovation and industrial marketing researchers (Martín-de Castro, 2015). The impact and mechanism of absorbing external knowledge have been mostly examined in the context of—for example—technology innovation and open innovation (e.g., Crescenzi & Gagliardi, 2018; Maietta, 2015; Martín-de Castro, 2015; Spithoven, Clarysse, & Knockaert, 2010). Firms’ capacities to exploit and realize knowledge and information from external sources such as competitors, suppliers, and government, universities labs contribute to the creation of new technology knowledge (e.g., Cohen & Levinthal, 1990; Crescenzi & Gagliardi, 2018). Such knowledge absorption influences innovation activities and outcomes (e.g., Martín-de Castro, 2015).

Absorptive capacity is essential to design activities and design innovation since new design ideas often come from and need to be examined with collaborating parties such as suppliers, customers, and consultants. For example, suppliers with their own teams of prototypes could help to detect and solve the problems in product design (D'Ippolito, Miozzo, & Consoli, 2014). Sometimes, the materials that suppliers are able to provide influence the design of a product. For example, D'Ippolito et al. (2014) revealed in their study that furniture firms would focus on how to best use the properties of plastic materials in their chair shape designing rather than only pursue new designs of the chair. Since suppliers could also be a source of information and knowledge, appropriate supplier management and cooperating with suppliers with the edgiest technologies can advance technology innovation and performance (Afuah, 2000; McDermott & Handfield, 2000). Consultants are crucial to product design as well since consultants could give firms diversified perspectives and experience on innovation processes and technologies, with support resources (e.g., personnel from different backgrounds) (D'Ippolito et al., 2014).

University-industry collaboration has also been found to influence innovation (Rajalo & Vadi, 2017). Collaborating with universities or design schools is relevant to new design ideas since it spurs the knowledge from more formalized design education and young minds (D'Ippolito et al., 2014). Particularly, knowledge stemming from experiential "know-how" and "trial-and-error" is incubated since design schools could offer "offered more structured training courses centred on the concept and techniques of prototyping in design." (D'Ippolito et al., 2014, p. 1344). Institutional sources of information (e.g., through university-firm collaboration) may drive design activities. On the other hand, the university-industry collaboration on R&D has received constant attention (e.g., Howells, Ramlogan, & Cheng, 2012; Maietta, 2015). Firms' technology innovation often results from collaborating with universities' labs. It is reasonable to expect that university-industry collaboration (i.e., institutional sources of information) would drive firms' R&D activities.

In addition, since R&D investment from public institutions and universities is notably higher (Maietta, 2015) than design investment, institutional sources of information (through collaboration with universities, governments, or public R&D institutes) may exert higher impacts on R&D activities than design activities. Market sources of information (through collaboration with suppliers, customers, consultants, competitors, or commercial labs) may exert a similar level of impact on design well as R&D activities. Although no empirical study has shown the direct relationship between design absorption and design innovation, scholars (e.g., Abecassis-Moedas & Mahmoud-Jouini, 2008; D'Ippolito et al., 2014) have discussed the importance of design absorption to new design ideas and new product effectiveness. For example, Abecassis-Moedas and Mahmoud-Jouini (2008) have pointed out that external design consultants may bring "a diversity of ideas and views considerably beyond an internal corporate perspective" (p. 476). In this context, I expect that market sources of information are of a similar level of importance to design as well as R&D activities.

Hypothesis 1a. Market sources of information are positively related to design activities.

Hypothesis 1b. Market sources of information are positively related to R&D activities.

Hypothesis 2a. Institutional sources of information are positively related to design activities.

Hypothesis 2b. Institutional sources of information are positively related to R&D activities.

8.3. The Impact of Competition and Competitor Responsiveness on Design Activities and R&D Activities

The competitive strategy perspective states that firms should "find a position in its industry where it can best cope with these competitive forces or can influence them in its favor" (Porter, 1980, p. 31). Competition has received much discussion in the field of innovation. Competition is found to spur technology innovation and impact firms' performance, given the degree of competition intensity (e.g., Aghion, Bloom, Blundell, Griffith, & Howitt, 2005; Nickell, 1996). Nickell (1996) found that competition enhances firms' performance. The seminal paper from Aghion et al. (2005) shows that the relationship between competition and technological innovation is an inverted U-shape, indicating that competition may stimulate technological innovation as far as firms' performance increases, but the laggard firms may not have enough incentives to innovate when the market is too competitive.

For a firm to develop effective competitive strategies, it must have a good understanding of its primary market and other players in the market to make a better offering and possess a "favorable" position in the market (Candi & Saemundsson, 2008). It asks firms to be market-oriented and competitor-oriented (Kohli & Jaworski, 1990; Narver & Slater, 1990). Firms should continuously "monitor" competitors to understand and respond to competitors' long-term and short-term strengths and weaknesses so that firms can keep competitive in the market (Kohli & Jaworski, 1990; Narver & Slater, 1990). Firms with a market orientation culture, including competitor orientation, will see the better performance (e.g., Kohli & Jaworski, 1990; Narver & Slater, 1990). Firms' competitor responsiveness is driven by the organizational culture of competitor orientation (Homburg, Grozdanovic, & Klarmann, 2007; Narver & Slater, 1990). Competitor responsiveness means that firms have quick responsiveness to competitor changes (Homburg et al., 2007). Competitor responsiveness may not only influence market performance (e.g., Homburg et al., 2007) but also spawn new and creative product ideas (e.g., Im & Workman Jr, 2004). New and creative product ideas often appear when a firm seeks to monitor and respond to competition (Im & Workman Jr, 2004). If a firm is competitor responsive, it not only keeps monitoring and tracking competitors and is aware of the market trends but also takes action to quickly respond to the competitors' activities (Homburg et al., 2007; Im & Workman Jr, 2004). To stay competitive, firms may seek to introduce products that differentiate themselves from rival firms, and thus a competitor responsiveness strategy is likely to encourage innovative product ideas (Im & Workman Jr, 2004).

Previous new product studies primarily emphasized technology innovation. Does competition matter to design innovation, and should firms keep up with competitors for new product designs? According to Dan et al. (2018), competition should be highly relevant to design innovation since design innovation sees shorter development cycle and is easier to be replicated than technology innovation. Dan et al. (2018) found that design innovation appears more often than technology innovation in a rapidly changing and competitive market, and the main reason is that customers' desires for new design (e.g., a new shape or pattern) may grow and switch fast while new competitors keep entering the market in this type of market. In other words, if the market is competitive, firms should be more likely to conduct design activities (Dan et al., 2018). Conversely, technology innovation (usually from R&D activities) is harder to be replicated and requires more capital such as money and effort to be developed and thus less associated with competition than design innovation (Dan et al., 2018).

When a firm is competitor responsive, it should be more likely to invest in design and R&D activities than not being competitor responsive. The level of competition may also influence firms' design and R&D decisions. In this sense, I expect that the competition intensity of the market and firms' competitor responsiveness are related to design and R&D activities. However, the impacts of competition and competitor responsiveness on design activities might be higher than R&D activities since firms might be more likely to invest in design as they are in a relatively competitive market and are competitor responsive. Design activities may require less capital and a shorter development cycle and thus might be relatively easier to be implemented (Dan et al., 2018). Firms may consider that conducting design activities is a more practical strategy to respond to a competitive and dynamic market and to stay competitive in the market.

Hypothesis 3a. Competition intensity is positively related to design activities.

Hypothesis 3b. Competition intensity is positively related to R&D activities.

Hypothesis 4a. Competitor responsiveness is positively related to design activities.

Hypothesis 4b. Competitor responsiveness is positively related to R&D activities.

8.4. The Role of Product Development Resources in Design Activities and R&D Activities

The RBV suggests that resources owned by the firm are the primary source of a competitive advantage which differentiates some firms from the others (Barney, 1991; Wernerfelt, 1984). The resources include complex and collective knowledge, which may constitute "higher order" learning processes and determine the product offering(s) a firm could deliver (Barney, 1991; Dickson, 1996; Hunt & Morgan, 1996; Wernerfelt, 1984). The study from D'Ippolito et al. (2014) points out that knowledge creation may originate from the resources, routines, and practices used in product design and product development, which are used to meet the "functional or aesthetics considerations" (p. 1337).

Combining a “people, product, process and tool” framework (see p. 142) suggested by Fixson and Marion (2012), I examine product development-specific resources through three aspects (i.e., people-, process-, and tool-related factors). People-related factors include, for example, team composition and team communication (Fixson & Marion, 2012). Process-related factors refer to the process structures used in product development, examples including “concurrent engineering” and “Crashing” (Fixson & Marion, 2012). Tool-related factors are the advanced simulation tools used in product development, which could also be generally understood as “Information Communication Technologies (ICT)”, examples including CAD (Computer-Aided Design), CAM (Computer-Aided Manufacturing), and CAE (Computer-Aided Engineering) (Fixson & Marion, 2012).

I use three variables to capture people, process, and tool factors. Specifically, I discuss the roles of cross-functional design teaming (as of people factor), design or information control technologies (as of tool factor), and concurrent engineering (as of process factor) in their relationships to design knowledge creation. I seek to understand how those resources and processes contribute to design activities and whether they affect design and R&D activities differently.

Beverland (2005) points out how designers struggle with their own design value and commercial-oriented value. Designers and marketers have different values and perceptions concerning new product introduction, design language, product quality, functional integration, cost control, and other issues in product development (e.g., Beverland, 2005; Micheli, Jaina, Goffin, Lemke, & Verganti, 2012; Mukhopadhyay & Gupta, 1998; Zhang, Hu, & Kotabe, 2011). In some firms, the design and product development departments are separate teams (e.g., the findings from D'Ippolito et al., 2014, pp. 1340-1341). Companies such as Moet Hennessey Louis Vuitton (LVMH) (Wetlaufer & Arnault, 2001) and BMW (Bangle, 2001) deliberately separated designers from other business functions to ensure designers' freedom and space in artistic creativity and inspiration (Bangle, 2001; Beverland, 2005; Wetlaufer & Arnault, 2001). Whether to integrate design with other business activities is a controversial topic (Beverland, 2005). Marketing-design interface and designers' involvement in new product development is a topic that gets continuous attention, examination, and exploration (e.g., Beverland, Micheli, & Farrelly, 2016; Micheli et al., 2012; Zhang et al., 2011).

Communication between designers and marketing, sales, research, or engineering departments is essential in product development, and having a cross-functional team that can perform such duty is a critical design management practice (Chiva & Alegre,2007). Such a team should be able to motivate the conversation of design with all other units related to product development (Chiva & Alegre, 2007). A cross-functional design team integrates design with other business activities (e.g., engineering, marketing, R&D, manufacturing) that facilitate product development. The function and form of a product need to be considered together by effectively connecting engineering designers (or engineers), industrial designers, and other functions. Generally, a diversified and cross-functional team could enhance "integrated problem-solving" (Verganti, 1999, p. 369), is essential to make contributions to new product ideas and development (Qiu, Qualls, Bohlmann, & Rupp, 2009), and has a strong relationship with innovation success (Sarin, 2009). Cross-functional design teaming helps to motivate new design ideas through effectively connecting design with other functions in the firm (e.g., Chiva & Alegre, 2007; Luchs & Swan, 2011). In the same sense, it also facilitates the development of new technology ideas while it increases the integration of engineers and R&D functions with design, marketing, manufacturing, and other related activities.

Hypothesis 5a. Cross-functional design team is positively related to design activities.

Hypothesis 5b. Cross-functional design team is positively related to R&D activities.

Technology is imperative to push new product design and product development (Abernathy & Utterback, 1978; Sun & Linton, 2014). Adopting design and ICT technologies is relevant to new product ideas and design innovation since these technologies (especially simulation) would greatly enhance the flexibility and efficiency of ideation and problem-solving in product design and product development (D'Ippolito et al., 2014; Fixson & Marion, 2012; Thomke & Fujimoto, 2000). Design and ICT technologies such as simulation, rapid prototyping, and Computer-Aided Design (CAD) software are broadening the means and methods of prototyping with much greater flexibility (D'Ippolito et al., 2014; Verganti, 1999).

Facilitated by these design technologies, designing becomes more efficient, flexible, and less expensive, mainly because the traditional "trial-and-error" phases in product design now can be implemented, tested, and iterated on virtual platforms (D'Ippolito et al., 2014; Fixson & Marion, 2012). In this context, new design ideas are boosted as they can be tested on digital platforms at a low cost before making a physical prototype (D'Ippolito et al., 2014; Fixson & Marion, 2012). However, there is a potential downside to over-reliance on digital prototyping. For example, it could be problematic if young designers have no experience "realizing a physical prototype" since it means they lack a meaningful understanding of the physical materials and so as the feasibility of the materials (D'Ippolito et al., 2014, p. 1344).

Overall, design and ICT technologies are expected to facilitate design activities and new product development. Some advanced tools may facilitate R&D activities as well since the programs could "simulate and test product functions (e.g., CAE) and manufacturing processes (e.g., MoldflowTM, which helps engineers analyze the plastic injecting molding process)" (Fixson & Marion, 2012, p. 142). Notwithstanding, the impact of design and ICT technologies should be stronger on design than R&D activities since these technologies are more relevant to design.

Hypothesis 6a. Adoption of design or information control technologies is positively related to design activities.

Hypothesis 6b. Adoption of design or information control technologies is positively related to R&D activities.

Concurrent engineering is a product development process that is opposed to the traditional practice of sequential product development (Chiva & Alegre, 2007; Dickson, Schneier, Lawrence, & Hytry, 1995; Dowlatshahi, 1993; Fixson & Marion, 2012). Concurrent engineering takes all product attributes (e.g., manufacturability, aesthetics, ergonomics, durability, reliability) into account simultaneously in the early designing stage (Dowlatshahi, 1993). The benefits of concurrent engineering include avoiding expensive redesign, generating more simply manufacturable components, and reducing the time and duplicated procedures in product development to enhance overall efficiency (Dowlatshahi, 1993; Fixson & Marion, 2012).

In addition, this process may facilitate the learning and understanding of different aspects of a product since all product attributes are required to be considered in the early development stage. Achieving this goal would require conversations and communication between designers, marketers, engineers, and other related functions (Chiva & Alegre, 2007). This process thus may open the doors for new ideas of product form (or design) and function (or technology) and allow these ideas to be examined given their manufacturability, feasibility, and marketability altogether in the interim (Dowlatshahi, 1993). However, this process's "side effect" may hinge on the potential rework caused by uncertainties in the project or procedure scheduling (Fixson & Marion, 2012).

Hypothesis 7a. Adoption of concurrent engineering is positively related to design activities.

Hypothesis 7b. Adoption of concurrent engineering is positively related to R&D activities.

Chapter 9

Study 2. Research Method and Data

9.1. Data and Sample

This study uses data from the *Survey of Innovation and Business Strategies (SIBS) 2017* and the *Business Registry (BR)*. The data was collected and provided by Statistics Canada. The BR provides enterprises' demographic information. The SIBS is a business survey that collects data and information regarding Canadian enterprises' innovation and business strategies. The SIBS follows the Oslo Manual and is comparable to the *Community Innovation Survey* (CIS) which is used by European member countries (Czarnitzki & Thorwarth, 2012). The survey respondents include CEOs and managers from the business enterprises (Grimpe et al., 2017). This study is based on a sample that consists of 2768 firms across all manufacturing industries.

9.2. Variable Description

9.2.1. Dependent variables. Design activities and R&D activities are the two dependent variables of this study. **Design activities** is a binary variable indicating whether a business conducted innovation activities such as design activities in 2017. **R&D activities** is a binary variable indicating whether a business conducted innovation activities such as research and experimental development in 2017. These two variables are innovation outcomes that account for whether firms conducted design as well as R&D activities for the introduction of innovations. The questions related to whether a firm conducted a certain type of innovation activity have been used as firms' decision outcomes by innovation researchers (e.g., Hashi & Stojčić, 2013).

9.2.2. Independent variables. The SIBS 2017 asked respondents to indicate the different types of collaboration partners concerning their innovation activities during the three years 2015 to 2017. These collaborative partners include:

- "Suppliers of equipment, materials, components or software"
- "Clients or customers from the private sector"
- "Clients or customers from the public sector"
- "Competitors or other businesses in the sector"
- "Consultants and commercial laboratories"
- "Universities, colleges or other higher education institutions"
- "Government, public or private research institutes"

The variable of **"institutional sources of information"** takes value 1 if a firm indicates any collaborative relationship with universities, colleges or other higher education institutions or government, public or private research institutes, and 0 otherwise (Crescenzi & Gagliardi, 2018; Hashi & Stojčić, 2013). The variable of **"market sources of information"** takes value 1 if a firm indicates any collaborative relationship with suppliers, customers from private or public sector, competitors, or consultants, and 0 otherwise (Crescenzi & Gagliardi, 2018; Hashi & Stojčić, 2013).

Competitor responsiveness takes the value 1 if a firm indicates making changes to respond to competition in 2017 and 0 otherwise. The changes include but are not limited to "changing the quality of its goods or services (products)", "adopting new technology or a new process", "changing its marketing expenditures or marketing strategy", etc. I use this construct to measure if a firm monitored its competitors and took actions to respond to competition (e.g., Homburg et al., 2007; Martin & Grbac, 2003). **Competition intensity** is a binary variable that takes 1 if firms indicate having more than five competitors in the main market in 2017, otherwise 0 (Nickell, 1996).

Cross-functional design team indicates whether a firm had a cross-functional design team in 2017. It takes the value 1 if a firm did; otherwise, 0. **Concurrent engineering** indicates whether a firm adopted concurrent engineering in 2017. It takes the value 1 if a firm did; otherwise, 0. The variable of **design or information control technologies** indicates whether a firm adopted design or information control technologies in 2017. It takes the value 1 if a firm did; otherwise, 0.

9.2.3. Control variables. As for control variables, **firm size** takes the logarithmic form of a firm's average number of employees during the year of 2015 to 2017, to capture the "economies of scale and scope" (e.g., Czarnitzki & Thorwarth, 2012, p. 883). **Firm age** takes the logarithmic form of a firm's age and is used to capture a firm's experience in its market (e.g., Czarnitzki & Thorwarth, 2012). **Fabrication technologies** indicate whether a firm adopted advanced technologies such as fabrication or processing technologies. It takes the value 1 if a firm did; otherwise, 0. Fabrication technologes may support design materialization and facilitate product development (Valamanesh & Shin, 2013). **Industry dummies** are formed based upon three-digit North American Industry Classification Systems (NAICS) codes used in Canada. Twenty-one industries dummies are used to account for the industry sectoral factors that might not be observed (see Table B in Appendix B).

9.3. Model Specification

A bivariate probit regression (Greene, 2003) is used to examine the factors related to design activities and R&D activities. Probit regression modeling is considered when the dependent variable is a binary outcome. A bivariate probit model is applied since design and R&D activities—two outcomes examined in the study—could be correlated in firms' decision-making. A bivariate probit model could account for the potential correlation of the disturbances (Greene, 2003) from equations that have design and R&D activities as decision outcomes, respectively.

A bivariate approach is required to model two complementary innovation activities (e.g., Santamaría et al., 2012). The decisions of design and R&D activities might be interrelated since design and R&D activities could simultaneously occur (e.g., Dan et al., 2018; Rubera, 2015; Rubera & Droge, 2013; Talke et al., 2009). Unlike the modeling technique, such as the binominal approach, a bivariate approach doesn't assume that design and R&D decisions should be substitutes (e.g., Santamaría et al., 2012). In addition, a bivariate probit model facilitates the comparisons of the antecedents of design and R&D activities since it allows the explanatory variables (i.e., the antecedents of design and R&D activities) to vary between design and R&D outcomes (Santamaría et al., 2012). This technique allows me to examine the differential impacts of the proposed antecedents of design and R&D activities.

Chapter 10

Study 2. Results

10.1. Descriptive Statistics

Table 6 shows the descriptive statistics of all variables. It gives an overview of Canadian manufacturing firms' innovation activities in 2017 as well as a pattern of proposed antecedents. First, R&D activities (mean = 0.523) occur more frequently than design activities (mean = 0.360). Since study 2 captures firms' innovation activities in 2017, study 1 captures firms' innovation introductions from 2015 to 2017, and the two studies use the same sample (n = 2768), I compared the innovation activities conducted in 2017 and innovation introductions from 2015 to 2017.

While 19.9 percent of firms introduced design innovation from 2015 to 2017, 36 percent conducted design activities in 2017. On the other hand, while 53.4 percent of firms introduced technology innovation from 2015 to 2017, 52.3 percent conducted R&D activities in 2017. Although innovation activities may not necessarily lead to innovation introductions, this observation may still reflect firms' overall growing awareness of design.

Table 7 shows the correlation of all independent and control variables. Multicollinearity is examined and not found to be an issue in the study since individual and mean VIF are all below 2. Institutional sources of information and market sources of information have a relatively higher correlation (0.47) than the other variables.

Fabrication (or processing) technologies, as they could support "design materialization" (Valamanesh & Shin, 2013), also has a moderate correlation (0.45) with design (or information control) technologies.

Table 6

Descriptive Statistics

	Mean	**Std.Dev.**
Design activities	0.360	0.480
R&D activities	0.523	0.500
Institutional sources of information	0.102	0.303
Market sources of information	0.207	0.405
Competitor responsiveness	0.674	0.469
Competition intensity	0.511	0.500
Cross-functional design team	0.285	0.452
Concurrent engineering	0.192	0.394
Design or information control technologies	0.260	0.439
Firm size (log)	4.515	1.163
Firm age (log)	2.959	0.559
Fabrication	0.355	0.479

Table 7

Correlation Table

		1	2	3	4	5	6	7	8	9	10	VIF
1	Institutional sources of information											1.34
2	Market sources of information	0.47										1.39
3	Competitor responsiveness	0.12	0.16									1.15
4	Competition intensity	0.04	0.04	0.20								1.09
5	Cross-functional design team	0.14	0.20	0.14	0.00							1.26
6	Concurrent engineering	0.12	0.15	0.08	-0.04	0.29						1.22
7	Design or information control technologies	0.19	0.23	0.18	0.04	0.23	0.24					1.36
8	Firm size (log)	0.17	0.12	0.09	0.08	0.23	0.10	0.12				1.19
9	Firm age (log)	0.00	0.01	-0.01	0.01	0.00	0.01	0.03	0.11			1.05
10	Fabrication	0.16	0.20	0.18	0.02	0.20	0.21	0.45	0.16	0.03		1.34
11	Industry dummies	0.03	0.05	0.03	-0.08	0.19	0.21	0.14	-0.04	0.07	0.12	
										Mean VIF		**1.34**

Note. Industry dummies are calculated in mean VIF (not presented).

10.2. Estimation

Table 8 shows the results of the base bivariate probit model. The correlation of the disturbances from two probit equations is positive and highly significant ($p < .001$), justifying a bivariate probit modeling choice. It also indicates that firms' innovation activities such as design and R&D are interrelated. Design and R&D activities could be simultaneous and complementary decisions.

Institutional sources of information and market sources of information have highly significant and positive impacts on both outcome variables. The impact of institutional sources of information is much higher on R&D than design activities (β = 0.557 vs. β = 0.190). The impact of market sources of information is similar to R&D and design activities (β = 0.452 vs. β = 0.469). Noteworthy, market sources of information are more related to design activities than institutional sources of information (β = 0.469 vs. β = 0.190).

Competitor responsiveness has a highly significant and positive impact on both outcome variables, with the impact higher on design activities (β = 0.426) than R&D activities (β = 0.287). Competition intensity is not significantly related to either of the outcomes. The insignificance of competition intensity might be explained by its measure. Since firms don't report the exact number of competitors but only the level of competitor numbers (e.g., 0; 1; 2-3; 4-5; 6-10), I composed this variable as a dummy, referring to the cutoff used by Nickell (1996). The cutoff could be arbitrary. Having exact competitor numbers might better facilitate the modeling. Moreover, the industry sector may impact how competition intensity is related to the outcome variables since some industry sectors may see more competitors, on average, than the others. The interactive effect of the industry sector and firm-level competition intensity may exert different impacts.

Cross-functional design team, design or information control technologies, and concurrent engineering all have highly significant and positive impacts on both outcome variables. The impact of design or information control technologies is higher on design ($\beta = 0.447$; $p < .001$) than R&D activities ($\beta = 0.226$; $p < .001$). The impacts of cross-functional design team and concurrent engineering are similar to R&D and design activities.

In addition, firm size has significant impact on R&D but not design activities. Firm age is not significantly related to either design or R&D activities. Adoption of fabrication technologies is significantly and positively related to design as well as R&D activities.

Table 8

Bivariate Probit Analysis: Design Activities and R&D Activities

	Design Activities	R&D Activities
Independent		
Institutional sources of information	0.190*	0.557***
Market sources of information	0.469***	0.452***
Competitor responsiveness	0.426***	0.287***
Competition intensity	0.004	0.042
Cross-functional design team	0.343***	0.297***
Concurrent engineering	0.349***	0.339***
Design or information control technologies	0.447***	0.226**
Control		
Firm size	0.002	0.078**
Firm age	-0.009	0.005
Fabrication	0.234***	0.285***

Notes. $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

Intercept is included (not shown); Industry dummies are included (not presented).

I also performed several Wald tests (e.g., Santamaría et al., 2012) to further examine whether the impacts of independent and control variables are statistically different on design versus R&D activities (Chow, 1960). I attempted to understand if and how the proposed antecedents may impact design and R&D activities and to examine further if there could be a differential mechanism underneath firms' decision of design and R&D activities. The results of the Wald tests (see Table 9) show that the impacts of institutional sources of information, competitor responsiveness, and design or information control technologies are statistically different on design versus R&D activities.

Institutional sources of information exert much higher impacts on R&D than design activities. Competitor responsiveness impacts design more than R&D activities. Design or information control technologies are more related to design than R&D activities. The impacts of firm size on design and R&D activities are also significantly different. Firm size is not significantly related to design activities, though. On the other hand, market sources of information, cross-functional design team, and concurrent engineering are all significantly related to the two innovation outcomes but don't impact them much differently.

Table 9

Wald Tests: Results of Beta Difference Tests

	βdesign value	βR&D value	Chi-sq.	p-value
Independent				
Institutional sources of information	0.190*	0.557***	**8.89**	**0.0029**
Market sources of information	0.469***	0.452***	0.04	0.8460
Competitor responsiveness	0.426***	0.287***	**3.86**	**0.0496**
Competition intensity	0.004	0.042	0.34	0.5579
Cross-functional design team	0.343***	0.297***	0.39	0.5346
Concurrent engineering	0.349***	0.339***	0.01	0.9111
Design or information control technologies	0.447***	0.226**	**8.00**	**0.0047**
Control				
Firm size	0.002	0.078**	6.82	**0.0090**
Firm age	-0.009	0.005	0.06	0.8060
Fabrication	0.234***	0.285***	0.50	0.4778

Note. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Based on the above result tables, I can conclude that all hypotheses are accepted except for H3a and H3b (see Table 10).

Table 10

Hypotheses Accepted / Rejected

H1a: Market sources of information are positively related to design activities.	Accepted
H1b: Market sources of information are positively related to R&D activities.	Accepted
H2a: Institutional sources of information are positively related to design activities.	Accepted
H2b: Institutional sources of information are positively related to R&D activities.	Accepted
H3a: Competition intensity is positively related to design activities.	Rejected
H3b: Competition intensity is positively related to R&D activities.	Rejected
H4a: Competitor responsiveness is positively related to design activities.	Accepted
H4b: Competitor responsiveness is positively related to R&D activities.	Accepted

H5a: Cross-functional design team is positively related to design activities.	Accepted
H5b: Cross-functional design team is positively related to R&D activities.	Accepted
H6a: Adoption of design or information control technologies is positively related to design activities.	Accepted
H6b: Adoption of design or information control technologies is positively related to R&D activities.	Accepted
H7a: Adoption of concurrent engineering is positively related to design activities.	Accepted
H7b: Adoption of concurrent engineering is positively related to R&D activities.	Accepted

I checked common method variance bias by running the same analysis on sub-samples that are randomly generated. The result patterns remain the same with the sub-samples except for only one independent variable—institutional sources of information. Common method variance bias is not much of a concern if the sub-sample generates a similar pattern (Lee, Lee, & Garrett, 2017). In addition, common method variance bias could be mitigated by creating a psychological separation of measurements (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). This study's outcome variables and explanatory variables are from separate sections of the SIBS questionnaire, which breaks respondents' psychological inertia. Moreover, respondents' "affective states and the tendency to respond in a socially desirable manner" are considered as the two main reasons that trigger common method variance (Podsakoff et al., 2003, p. 889). The design of the SIBS questions—mostly in a binary form (e.g., Yes or No)—mitigates the potential influence of respondents' affective states. Since the SIBS is conducted by Statistics Canada, which is a trustworthy government institution, it also reduces the social desirability bias (Hecker & Ganter, 2013).

Chapter 11

Study 2. Theoretical Contributions and Managerial Implications

This study contributes to the body of literature on design innovation by examining the antecedents of design activities as well as R&D activities. This study mainly explores what spurs firms' innovation activities such as design (as well as R&D) by accounting for firms' strategic factors such as competitor responsiveness, absorptive capacity (captured by two variables—market sources of information and institutional sources of information), and product development resources (captured by three variables—cross-functional design team, design or information control technologies, and concurrent engineering). This study also investigates the differential impacts of the antecedents on design versus R&D activities. Empirical and quantitative evidence in this study is drawn from the analyses of large-scale data of Canada's manufacturing industries.

The first important finding is that competitor responsiveness is an indicator of design as well as R&D activities. It means that when firms monitor competition in the market and take actions to respond to the competition, they are more likely to carry out design and R&D activities than firms that are not competitor responsive. The empirical evidence also shows that the impact of competitor responsiveness is higher on design than R&D activities. It may imply that competitor responsiveness is more related to design activities especially given a short product development cycle (i.e., the year of 2017 from this study) than R&D activities. Firms may choose to conduct design over R&D activities to stay competitive given a short product development cycle since design asks for less investment and is easier to implement (Dan et al., 2018).

Market sources of information (from collaboration with suppliers, consultants, competitors, and customers) and institutional sources of information (from collaboration with universities, colleges, government, research institutes) are used to capture firms' absorptive capacity in this study. I found that both market and institutional sources of information are the antecedents of design and R&D activities. Firms' collaboration with suppliers, consultants, customers, universities, and research institutes facilitates the generation of new design and R&D ideas. The empirical evidence shows that market sources of information are more related to design activities than institutional sources of information are. Collaborating with external parties such as suppliers, consultants, and customers is crucial to firms' decisions to conduct design activities. Also, institutional sources of information exert higher impacts on R&D activities than design activities. Notwithstanding, collaborating with universities and colleges still promotes design activities. This study provides empirical evidence showing the differential impacts of market and institutional sources of information on design versus R&D activities.

I made another contribution by conceptualizing product development resources and empirically testing their relationships with design activities (versus R&D activities). My empirical evidence supports that cross-functional design teaming, design or information control technologies, and concurrent engineering are the antecedents of design as well as R&D activities. The significant role of design and ICT technologies has been discussed by quite a few design and product development studies (e.g., D'Ippolito et al., 2014; Fixson & Marion, 2012) but has not been empirically tested. My empirical evidence stresses that adopting design and ICT technologies is highly important to design activities and its impact on design is greater than R&D activities. Moreover, whether to integrate design with other functions in product development is still a debatable topic (Beverland, 2005). The empirical evidence from this study demonstrates that having a cross-functional design team leads to a higher possibility of design activities than not having it.

Besides, this study shows that firms' "economies of scale and scope" (captured by employee number as a control variable) (e.g., Czarnitzki & Thorwarth, 2012, p. 883) are related to R&D but not design activities. The reason could be that R&D is usually more capital intensive than design activities (Dan et al., 2018). Firm age is used to capture firms' market experience (e.g., Czarnitzki & Thorwarth, 2012). My empirical evidence shows it is not related to either design or R&D activities. Adoption of fabrication technologies, used as another control variable, is found to be related to design as well as R&D activities.

From a practical perspective, the study's results shed light on what firms' strategic factors may lead to design and R&D activities, which typically lead to the introduction of design and technology innovations. First, firms need to keep tracking the markets and quickly respond to competitors' changes to stay innovative and competitive. Since design innovation doesn't require as much capital and development time as technology innovation and R&D does, conducting design activities could be a more effective decision in a market that sees fast-changing consumer preferences and competition forces (Dan et al., 2018; Verganti, 2009). Specifically, managers may consider adopting competitive intelligence-related tools to monitor competitors (Das, 2010). In addition, firms may consider building up their marketing research and design capability to capture the changes in customers' tastes and quickly respond with product design.

As firms seek to develop their own design capabilities, they could be aware that a cross-functional design team, design or information control technologies, and concurrent engineering process open the possibilities for innovative design. Design or information control technologies that include simulation, rapid prototyping, and CAD (D'Ippolito et al., 2014; Fixson & Marion, 2012; Verganti, 1999) are some of the most important design resources that firms need to acquire. Moreover, a cross-functional design team that integrates designers, marketers, and engineers (e.g., Chiva & Alegre, 2007) and a concurrent engineering facilitate design activities as well. In addition, design capabilities may also derive from firms' in-house design activities (as of internal knowledge source) and external collaborations (as of external knowledge source) (e.g., Crescenzi & Gagliardi, 2018; Czarnitzki & Thorwarth, 2012; Hashi & Stojčić, 2013; Santamaría et al., 2012). A cross-functional design team could also facilitate the integration of these internal and external knowledge sources.

Chapter 12

Study 2. Conclusion and Future Directions

This study seeks to explore the potential antecedents of design as well as R&D activities in the context of Canadian manufacturing firms. Firms' strategic factors such as competitor responsiveness, absorptive capacity (captured by "market sources of information" and "institutional sources of information"), and product development resources (captured by "cross-functional design team", "design or information control technologies", and "concurrent engineering") are found to be the antecedents of design as well R&D activities. Moreover, competitor responsiveness and design or information control technologies matter more to design than R&D activities. Institutional sources of information lead to higher possibilities of R&D than design activities. Market sources of information and institutional sources of information both lead to design activities, but market sources of information are more relevant. Cross-functional design team and concurrent engineering are equally important to design and R&D activities. These findings advance the understanding in terms of the antecedents of design activities and thus constitute the key contribution of this study.

The study is not without limitations, though. One limitation is from this study's cross-sectional nature, which might be addressed as researchers could have multiple waves of the SIBS data in the future. Another limitation relates to the SIBS questions, which lack design-specific information. For example, firms' collaboration with design consultants could be a factor important to design activities. The SIBS questionnaire, although asks whether firms collaborate with external consultants, doesn't specify what type of consultants they are. Firms' number of designers and design training (Candi, 2016) may also impact design activities; however, the SIBS doesn't have such information. As design is becoming a new topic, more design-specific questions are called to be considered and developed by the SIBS. Furthermore, the present scope of manufacturing sectors advances the understanding of design, mainly in business-to-consumer industries. Design may differ in its mechanism in service industries. Understanding design activities and design innovation in service industries could be another direction for future research.

Appendix B

Table B

Manufacturing Sectors

Code	Industry Sector
311	Food manufacturing
312	Beverage and tobacco product manufacturing
313	Textile mills
314	Textile product mills
315	Clothing manufacturing
316	Leather and allied product manufacturing
321	Wood product manufacturing
322	Paper manufacturing
323	Printing and related support activities
324	Petroleum and coal product manufacturing
325	Chemical manufacturing
326	Plastics and rubber products manufacturing
327	Non-metallic mineral product manufacturing
331	Primary metal manufacturing
332	Fabricated metal product manufacturing
333	Machinery manufacturing

334	Computer and electronic product manufacturing
335	Electrical equipment, appliance and component manufacturing
336	Transportation equipment manufacturing
337	Furniture and related product manufacturing
339	Miscellaneous manufacturing

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