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Exploring the sources of design innovations: Insights from the computer, communications and audio equipment industries

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Abstract

Whereas business research has focused on the impact of design innovations on market response and financial performance, the sources of design innovations, as opposed to those of technological innovations, have largely escaped investigation. In this research, we examine the organizational, financial, and environmental drivers of design innovations and how they contrast to technological innovations. Our study utilizes a unique dataset encompassing a 10-year window of innovation output drawn from the computer, communications, and audio and video equipment manufacturing industries. Our results suggest that design innovations are driven primarily by investments in research and development and slack organizational resources. Interestingly, we find that design innovations are more prevalent in smaller but fast-growing markets as opposed to technology innovations, which are prevalent in larger markets. Contrary to expectations, we find no association between marketing investments and design innovations. Our research contributes to the extant business literature by considering the sources of design innovations separately from the sources of technology innovations. We also contribute to the literature by distinguishing design and technology patents, developing a deeper understanding of design innovation, and illuminating a lesser understood source of competitive advantage for firms.

Keywords

Design, Design innovation, Technological innovation, Patents, Poisson model

Introduction

"Innovation" as a field of study is a robust topic across many disciplines. It has been studied both as a product of organizational assets, culture and processes (Tellis et al., 2009; Sethi and Iqbal, 2008) and as a driver of various performance metrics (Sorescu et al., 2003). While the most common characterization of innovations is as being either incremental or radical (i.e., disruptive) (Tellis et al., 2009), an alternate and more tangible characterization is on the basis of the intellectual property which drives them.

From a patent-based perspective, innovations can either be utilitarian or technological in nature, where the innovation, typically an improvement in the underlying technology, results in a functional benefit; or a design innovation, where a change in the external appearance of the product is the source of innovation (Rubera and Droge, 2013; Eisenman, 2007; Verganti, 2006). Rubera and Droge (2013) and Verganti (2006) point out that most research has focused on technology innovations and less on design innovations. This may be because, according to United States Patent and Trademark Office (USPTO) data, there is more than a 10:1 ratio between utility and design patents issued.[1] Interestingly, an increasingly large number of firms seem to be committing greater resources towards the pursuit of design innovations. While some firms such as Sony, Samsung, LG, and Apple have a long history of design-focused innovation, others are new to this game. Competing through design may have reached a peak with Apple Inc.'s allegations that the Samsung Galaxy 11 tablet and Galaxy Nexus smartphone had copied several of the design features from Apple's own iPad tablet and iPhone smartphone. Following a ruling in a United States district court, Samsung had to change features and make cosmetic tweaks to release its tablet under the new name, Galaxy Tab 10.1 N, and was ordered to pay $930 million in damages (Kendall, 2016).

A growing body of research has considered consumer reactions to product design (Bloch, 2011; 1995), the impact of product design on market share (Jindal et al., 2016), and the differential impact of technology versus design innovation on firm financial performance (Rubera and Droge, 2013). While researchers have some understanding of the outcomes of design innovation—for instance, increased positive consumer response and the resulting growth in market share and firm financial performance—we do not have a deep enough understanding of the firm characteristics that lead it to being successful in the development of design innovation. In other words, while recent work has established the performance benefits of design innovations (Rubera and Droge, 2013) and the benefits of including design at many levels of the new product development process (Roper et al., 2016), we need to more deeply understand the organizational and environmental antecedents of design innovation. That is the fundamental objective of this research.

In this study we examine the antecedents of design innovations, considering the organizational resources, financial management strategies, and environmental factors that are associated with their creation. Rather than looking at design innovations in isolation, we contrast the predictors and outcomes of a design innovation emphasis against a more traditional technology (i.e., "utility") innovation focus. Thus, the fundamental research questions explored here are: What are the organizational antecedents of a technology innovation focus versus a design innovation focus (as measured by intellectual property outputs), and how do they differ?

To answer these questions, we utilize a unique data set assembled from multiple sources, which allows us to look at a 10-year window of innovation output in the form of design and technology innovations, measured through patents. The data set includes 770 firm observations, including over 4000 design innovations and over 72,000 technology innovations in the computer, communications, and audio and video manufacturing industries. The results provide valuable insights for managers trying to strategically shape their organizations for various types of innovation outcomes.

This study contributes to the literature in several ways. First, we consider the nature and potential importance of design innovations, a distinct type of innovation of growing importance, which has not, with very few exceptions (e.g. Rubera and Droge, 2013), been considered in the literature. Understanding this phenomenon deepens our understanding of innovation in general, and how different forms may emerge from an organization and ultimately influence performance. Second, we decouple the concept of "patents," which has been studied in the past, into its two major forms, and highlight the different forces at play in their genesis. We then consider the differential sources of those patent types, as well as how they interact with one another, a topic that has not been previously considered. Third, by developing a deeper understanding of design patents we help illuminate the source of competitive advantage for firms which base a large part of their corporate strategy on the pursuit of design excellence. Finally, this work extends existing literature that attempts to understand the nature of design-driven strategy and how it may differ from traditional approaches to marketing and innovation. It also represents a first step in understanding an increasingly important direction in innovation strategy.

Influences on design versus technology innovation

While both design and technology innovations can be legally protected intellectual property, a close inspection reveals the two are quite different in their nature. Design innovation places a priority on novel appearance over novel functionality (Eisenman, 2007; Rindova and Petkova, 2007). Thus, issues like form and aesthetics take precedence over core technologies and disruptive innovation (Verganti, 2006; Postrel, 2003). Despite these differences, it is likely that these two forms interact in practice, as in the use of technology innovations as a platform on which to layer multiple design innovations (Rubera and Droge, 2013). An essential component of design is its role in linking many functions of business, and while its activities overlap with R&D and technological innovations, it contributes independently of both (Moultrie and Livesey, 2014; Walsh, 1996). Thus, it is important to consider the drivers of these different innovation outcomes within the same research setting.

2.1. The Role of R&D and marketing in technology and design innovations

Strategy, and specifically marketing strategy, deals with innovating and delivering innovations to the customer through enhanced value propositions (i.e., "value creation") and devising means to extract profits by creating transaction-based customer appeals that influence consumer choices and product comparisons (i.e., "value capture or appropriation") (Stefan, 2014; Mizik and Jacobson, 2003). Given that firms have limited resources, they trade-off between these two activities (March, 1991), and prioritize the use of resources between the two (Mizik and Jacobson, 2003). We argue that firms primarily invest in technology innovations as a means of value creation, and primarily in design innovations as a means of value capture. We also argue that the fundamental investments required to achieve value creation versus value capture differ. In industries that are primarily design driven (for instance, furniture and homeware), design innovations could be a source of both value creation and value capture.

Creation is often about creating product offerings with profound differences in features, reliability, and other performance attributes. At the heart of this approach is a focus on technological investment which should lead to tangible outcomes in the form of technology (or "utility") patents. While no single factor drives it, R&D spending is closely aligned with value creation (Mizik and Jacobson, 2003) and with the core technology development typically associated with the capability to build improved solutions to problems and meet customer needs (Gatignon and Xuereb, 1997).

On the other hand, we propose that firms pursuing an emphasis on value capture place more emphasis on the "moment of truth" when a consumer must choose between competing offerings in the marketplace. In this setting, more outwardly apparent differences may have greater influence on the purchase decision by communicating both functional and aesthetic information (Eisenman, 2013; Noble and Kumar, 2010; Rindova and Petkova, 2007). This is enhanced by marketing and sales efforts which can more easily highlight readily-apparent, superficial differences between products. Thus, marketing/sales investments in the promotion of design-oriented advantages should be more impactful in the pursuit of value capture. This relates to the concept of a sales orientation in which a firm engages in a high level of marketing and sales spending to stimulate short-term transactions (Noble et al., 2002).

Dutta et al. (1999) also find that a significant driver of firm performance in high tech industries is the marketing efforts of the firms involved. However, marketing is more important in products where the functional benefits are not easily communicated. Correspondingly, design innovations are more easily communicated by the firm, and in turn received by the consumer. Of a firm's marketing efforts, the effect of marketing on branding, creating differentiation and erecting barriers to entry are well documented (Aaker, 2012; Mizik and Jacobson, 2003; Golder, 2000; Bunch and Smiley, 1992). Eisenman (2013) also argues that there is a positive association between investments in "aesthetic" (design) innovation and the firm's expectation that users will value the sensory stimulations and second order meanings their products offer. Much of the intent of marketing investments is to create such associations.

Based on this evidence, we expect that investments in marketing and sales are intended to create visual points of difference and, therefore, will be positively associated with design innovations but not with technology innovations. Conversely, we also expect that investments in research and development will be positively related to technology innovation but not to design innovations. Therefore, we propose our first two hypotheses:

H1: Efforts in marketing and sales will be positively related to design innovations.

H2: Efforts in research and development will be positively related to technology innovations.

2.2. The role of market dynamics in technology and design innovations

Market dynamics are a well-established influence on many firm performance outcomes. In this context, we expect market size and market growth to be particularly influential factors. Larger markets tend to present more opportunities for firms, yet also typically include more intense competition. As a result, differentiation is harder to achieve, yet even more imperative than in smaller markets. Larger markets can support a greater number of competitors (Desmet and Parente, 2010), which may include both large, resource-rich players and a wide array of small and nimble firms. Symeonidis (1996) and Acs and Audretsch (1987) also show that larger markets are associated with greater innovative output, and a corresponding adoption of more advanced technologies as a result of having greater price elasticity of demand. This research also finds that in these markets, firms that are capital intensive, advertising intensive and where economies of scale and scope are achieved are likely to be more innovative. Large firms, capital intensity, advertising intensity and economies of scale are associated with mature industries. In considering the nature of technology versus design innovation, we propose that technology-based innovation is likely better suited to these larger markets. Acemoglu and Linn (2004), for instance, find that in the pharmaceutical industry, a one percent increase in the potential market size leads to a four percent increase in the entry of new products and technologies. Technology-based innovations are typically more difficult to replicate and have been shown to have a significant bottom line impact on firm performance (Sood and Tellis, 2009). Katila and Shane (2005) further suggest that market size justifies the greater investment in terms of time, money and effort typically more associated with technological development.

Conversely, the shorter development cycles generally associated with design innovation, often consisting of nothing more than a sketch of a unique shape or pattern, are better suited to the rapidly changing competitive dynamics of relatively smaller markets. In a situation of evolving customer tastes and the rapid entry of new competitors, we believe that design may constitute a more powerful strategic approach than traditional, engineering-driven innovation efforts (Verganti, 2009). Thus, we expect that smaller markets will give rise to more design innovations and the larger, more mature markets will encourage more technology-based innovations.

H3a: Technology innovations will be more prevalent in larger markets as compared to smaller markets.

H3b: Design innovations will be more prevalent in smaller markets as compared to larger markets.

The rate of growth of the market is another factor which should influence the development of innovations. We propose that faster growing markets should foster both forms of innovation, including design innovations for possible short-term advantages and longer-play technology innovations for more enduring effects. Strotmann (2007) finds that new ventures are more likely to survive in markets with growing demand conditions. Similarly, Park et al. (2002) demonstrate that in volatile industries with growing demand, such as semiconductors, firms pursue technological resources in order to remain innovative, and competitive (Song and Chen, 2014). Therefore, industries that exhibit growth in market demand are likely to support firms that innovate along both design and technology dimensions.

H4: Market growth will be positively associated with both design and technology innovations.

We expect that market conditions, particularly growth, will interact with some of the main effects on innovation types mentioned earlier. A growth market suggests an influx of new customers with undeveloped product preferences. This, in turn, gives rise to greater product variety, and allows for “substitution between goods, thereby raising the price elasticity of demand” (Desmet and Parente, 2010, p. 320). Given the rapidly evolving customer tastes which are prevalent in a high growth market, firms are more likely to make missteps by either misjudging customer tastes or not anticipating a competitive entrant. Thus, the efficiency and accuracy of marketing spending should weaken, resulting in lower productivity regarding the development of design innovations. This suggests:

H5a: Higher market growth will decrease the positive influence of marketing/sales efforts on design innovations.

Conversely, a higher growth market should likely have a positive effect on the link between technology investments and innovations. Higher growth markets tend to result in leaner product development cycles, a stronger tolerance for failure, and a willingness to place “big bets” in the pursuit of potentially dominant product (García-Granero et al., 2015). Thus, the same basic R&D spending level should result in a higher innovation output.

H5b: Higher market growth will increase the positive influence of research and development efforts on technology innovations.

Methods

3.1. Measuring innovation

In mainstream innovation research, awarded patents have often been used as the key metric of innovation output (Dahlander et al., 2014; Berrone et al., 2013). However, this stream has typically only considered one of the three major forms of patents award by the USPTO. So-called “utility patents” are by far the most common and "…may be granted to anyone who invents or discovers any new and useful process, machine, article of manufacture, or composition of matter, or any new and useful improvement thereof"[2]. During the 2015 calendar year, 298,407 utility patents were awarded by the USPTO, representing 91.7% of total issues[3]. Despite the dominance of this form, research and management thinking regarding the power of an emphasis on product design (Homburg et al., 2015) suggests that the second most common form, "design patents", may also be a worthy and profitable goal for organizations. Design patents (25,986 or 8.0% of total patents awarded in 2015) "…may be granted to anyone who invents a new, original, and ornamental design for an article of manufacture" (USPTO, 2011). The third patent form, "plant patents", are even more rare (only 1074 or 0.3% of total awarded in 2015).

Design patents can however be a measure of firm's interest and focus on design innovation for the following reasons. First, patents (regardless of whether they are design or utility), allow a firm to protect their intellectual property and protect their ability to be a monopolist, which is clearly a firm's most profitable strategy (as opposed to competition). Firms may invest in patenting designs (or for that matter, technologies) that they never use in a product, but it allows them to potentially reduce competition. Second, design patents cost less than utility patents (in terms of filing fees, they cost a quarter of the filing fee for a utility patent). They also have a shorter approval period (9–18 months, compared to an average of 2–3 years for utility patents). Design patents also remain in a firm's portfolio for 14 years without additional maintenance cost. Given that patents allow a firm to reduce competition, a rational firm should ideally pursue design patents especially given its lower overall cost (Dani, 2011). Finally, in the absence of patent protection, given the fact the designs are visible, they are easily infringed. This is in contrast to technological innovations that are hidden from view and can often be protected through trade secrets.

While utility patents have, perhaps understandably, received the bulk of research attention, this research considers the development of design patents, which have been shown to positively influence firm performance (Rubera and Droge, 2013). Rubera (2014) reports on data from the World Intellectual Property Organization which shows that worldwide design patents have grown by 123% over a ten-year span, whereas the total number of patents has grown by 86% in the same period. While the Apple-Samsung lawsuit has captured the headlines, DuMont and Janis (2013), in an examination of design patents, also highlight recent design-related lawsuits filed by Daimler AG, Crocs, and Kohler, and predict that as a result of a rising trend of patent filing, litigation pertaining to designs will become increasingly common worldwide. Even more recently, Chan et al. (2017) use design patents to identify patterns of design evolution, focusing on 'style turbulence'—'the year-to-year unpredictability of changes in a style's prevalence.' Following the strengthening of design patent rights in 1982 (DuMont and Janis, 2013), Chan et al. (2017) also discuss how "product designers are increasingly encouraged to 'think about patents' when creating a new form (Molotch, 2004, p. 28) and that many patent litigation cases have centered on designs." Given the growing number of firms choosing to patent designs, the growing interest in design patents among the academic community, the objective nature of this measure, and the increased enforceability of design patents, we study the organizational and environmental factors associated with a greater emphasis on these less common patents.

3.2. Empirical context, data and sample

This paper matches patent data from the Thomson Innovation Patent Database with firm specific data collected from the COMPUSTAT financial database. In this section, we present our data collection procedures and describe our data in detail. The empirical context for this study is a set of technology product manufacturing industries (see Table 1), which include computer and peripheral equipment manufacturing, communications equipment manufacturing, and audio and video equipment manufacturing industries. In addition to having a large number of publicly traded firms, we chose these industries because of their typically rapid product development cycles and their reliance on design as a marketing differentiator leading to a high incidence of observable design patents and corresponding design innovations. These industries also allow us to observe the utility patents and corresponding technological innovations. A ten-year window of economic activity for data collection was determined after an early test revealed a five-year window had an inadequate number of firms and patents available for analysis. The ten-year window from January 1, 1995 through December 31, 2004 was selected to minimize any anomalous market activity, such as that caused by the Great Recession in 2008. The period of our study featured only one recession from March–November 2001, which was relatively short and shallow (Kliesen, 2003).

Table 1. Summary of Design and Utility Patents Secured in Three Industries, by Year.

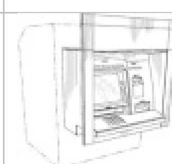
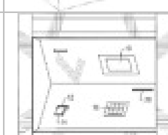
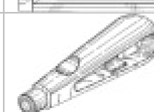
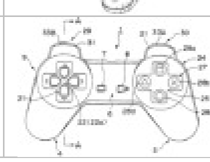
NAICS Code	NAICS Title	Year	No. of Design Patents	No. of Utility Patents
3341	Computer and Peripheral Equipment Manufacturing	1995	111	2729
		1996	103	3218
		1997	114	3329
		1998	104	4906
		1999	169	4940
		2000	239	4958
		2001	177	5569
		2002	167	5592
		2003	119	5198
		2004	66	4341
		TOTAL	*1369*	*44780*
3342	Communications Equipment Manufacturing	1995	118	1238
		1996	121	1372
		1997	141	1368
		1998	168	1861
		1999	115	1749
		2000	115	1945
		2001	60	1389
		2002	90	1411
		2003	103	1304
		2004	91	1308
		TOTAL	*1122*	*14945*
3343	Audio and Video Equipment Manufacturing	1995	54	789
		1996	91	907
		1997	82	906
		1998	123	1351
		1999	225	1456
		2000	275	1408
		2001	181	1453
		2002	194	1603
		2003	194	1605
		2004	187	1640
		TOTAL	*1606*	*13118*

A list of all firms within the three industries (Table 1) corresponding to the targeted NAICS (North American Industry Classification System)[4] codes was downloaded from COMPUSTAT, an online financial database, and checked to ensure US origin as the data would be subsequently evaluated against US financial market data. While a number of these firms were subsidiaries of other firms in the final list, because patent data is tied to the subsidiary name and each subsidiary includes a unique CUSIP (Committee on Uniform Security Identification

Procedure) code tying it to specific financial data, the subsidiary status of these firms was deemed inconsequential. Because firm names on patent applications tend to vary due to input diversity (i.e., level of included information and errors), they were manually checked to ensure that records were only downloaded from firm-level records with substantially, though in many cases not exactly, matching names. Our search resulted in a list of 597 firms and information for each was downloaded (including CUSIP data) to tie each firm to unique financial performance data.

The Thomson Innovation online database was then used to download records of all published patents in the ten-year window for all 597 firms in the CUSIP dataset. Of the total 597 firms, 220 appeared in the Thomson Innovation database, meaning 377 of these firms had no published patents. A final list of 88 firms from the list of 220 had at least one published design patent in the ten-year window resulting in a list of 76,818 individual patent records across these 88 firms of both utility and design patent types. This list of individual patent records was then analyzed to determine the count of design patents and utility patents for each of these 88 firms for each year in the ten-year window. All US design patents are prefixed with the string “usd,” which allowed us to differentiate the 4073 design patents from the 72,745 utility patents. Table 2 presents a sample of design and utility patents, and includes the patent titles, assignee name, a description, and an illustration of the design.

Table 2. Examples of Design and Utility Patents Filed for the Same Product.

Patent Type (Granted Date)	Patent Title (Patent Number)	Assignee (NAICS Category)	Claims	Description	Illustration
Design (2001-07-03)	Self-service terminal (USD444608S1)	NCR Corporation (3341)	1	Ornamental design for a self-service terminal, as shown and described	
Utility (2002-06-04)	Self-service terminal (US6400276B1)	NCR Corporation (3341)	29	A self-service terminal with fraud detection functionality	
Design (2001-10-02)	Punchdown Tool (USD448644S1)	Harris Corporation (3342)	1	Ornamental design for a punchdown tool	
Utility (1998-09-29)	Impact/no-impact punchdown tool for use with cut/no-cut or wire insertion blade assembly (US5813109 A)	Harris Corporation (3342)	24	A wire-insertion and/or cutting tool comprising a handle having an axial bore, in which a wire-insertion and cutting blade assembly holder is installed.	
Design (1998-12-08)	Controller for computer game (USD402317S)	Sony Corporation (3343)	1	Ornamental design for a controller for computer games	
Utility (1998-12-29)	Controller unit for electronic devices (US08436728)	Sony Corporation (3343)	22	A controller unit for controlling electronic devices	

Using these data sources, we assemble a unique data set that summarizes 4073 design patents to yield 770 observations at the Firm-Year level for firms traded in the US, observed between 1995 and 2004. Table 1 presents a breakdown of the number of design and utility patents for all years of observation for each of the industries in our dataset. Of the top twenty firms with granted design patents, twelve belong to computer and peripheral equipment manufacturing industry. While the number of design patents are comparable across the three industries, firms in the computer and peripheral equipment manufacturing industry have three times the number of utility patents.

3.3. Measures

Our goals behind identifying appropriate measures are to identify both firm and industry level variables, which drive a firm to launch design innovations. We start by presenting more details on the measures we use in our empirical analysis and we follow with an outline of the models we use to test our hypotheses.

Design Innovation (DES_INNOV$_{it}$): We measure design innovation for a firm *i* in time period *t* using a count of design patents filed for by the firm with the USPTO.

Technology (Utility) Innovation (TECH_INNOV$_{it}$): We measure technological innovation activity of a firm *i* in time period *t* using a count of technology or utility patents filed for by the firm with the USPTO.

Research and Development (R&D) Intensity (RD_INT $_{i(t-1)}$**):** We measure the R&D efforts of a firm *i* in time *t* by dividing lagged R&D expenditure for the firm by the lagged total assets.

Marketing Intensity (MKT_INT $_{i(t-1)}$): We measure the marketing efforts of a firm *i* in time *t* by dividing lagged SGA expenditure for the firm by the lagged total assets. Consistent with prior literature, we lag the measure by one year (McAlister et al., 2016; Feng et al., 2017; Narasimhan et al., 2006; Dutta et al., 2005; Wuyts et al., 2004; Dutta et al., 1999).

Market Size (MKT_SIZE $_{i(t-1)}$): The total size of the markets is indicative of the number and type of innovations launched by firms. New firms for instance, may be attracted toward markets that are too small or difficult for larger incumbents. We expect that technology innovations are more prevalent in newer, and therefore, smaller markets because we anticipate that consumers respond to functional benefits. On the other hand, we expect design innovations to be prevalent in more mature and therefore mostly larger markets, because of the stagnation of technology innovations (Christensen and Bower, 1996; Katila and Shane, 2005; Bhide, 1991). We measure market size as the logarithm or net industry sales.

Market Growth (MKT_GWTH $_{i(t-1)}$): We expect high growth markets to have a greater number of technology innovations, and low growth markets to have a greater number of design innovations. Higher growth rates could also be indicative of future opportunities for growth (Rao et al., 2004). We measure market growth as the percentage growth in industry sales over one year.

Control variables: Several control variables were added to the models to remove alternative influences and add to the clarity of our results.

Organizational Slack (ORG_SLACK $_{i(t-1)}$): Measures the availability of resources that could be utilized toward innovation activity, both design and utility (Dotzel et al., 2013; Lee and Grewal, 2004). While on the one hand, cash flow allows a firm to protect itself from uncertainty, it could also cause firms to invest in unwise and less than lucrative options at the discretion of the managers (Cyert and March, 1963; Davis and Stout, 1992; Jensen, 1986). In order to account for managerial decisions, we control for the net cash flow of the firm. We measure organizational slack as the ratio of net cash flow from operating activities to total assets.

Capital Intensity (CAPITAL_INT $_{i(t-1)}$): A firm's investment in fixed capital potentially affects its investment in innovation. We measure capital intensity as the ratio of investments made by the firm in fixed assets, namely plant property and equipment to total assets.

Financial Leverage (FIN_LEV $_{i(t-1)}$): Companies differ in the amount of debt they utilize to support various activities. We measure financial leverage as the ratio of long-term debt to total assets lagged by a year.

Firm Size (FIRM_SIZE $_{i(t-1)}$): As per prior literature, we control for firm size as the natural logarithm of the number of employees.

Working Capital Ratio (WORK_CAP $_{i(t-1)}$): Working Capital is measured as the ratio of working capital to total assets. Working capital is measured as current assets minus current liabilities. This is also referred to as the liquidity ratio. As with other variables, this too is lagged so as to account for the delayed effects.

Year Dummy Variables (YEAR$_t$): We control for unobserved systemic differences at the year level using dummy variables for each of the years in our data.

Industry Dummy Variables (INDUSTRY$_i$): We control for unobserved systemic differences, attributable to the industries using dummy variables for each of the industries in our data.

Table 3. Variables, measure, identification and sources.

Variable	Conceptual measure	Formula/Definition	Source
Design Innovation	Design based innovation activity	DES_INNOV = Count of Design Patents	USPTO, Thomson Innovation online
Technology Innovation	'Functional' innovation activity	TECH_INNOV = Count of Utility Patents	USPTO, Thomson Innovation online
R&D Intensity	Effort placed on technological investments in the year prior.	RD_EXP = R&D Expenses/Total assets	COMPUSTAT
Marketing Intensity	'Marketing/Selling Focus' in the year prior	MKT_EXP = SGA Expenses/ Total assets	COMPUSTAT
Market Size	New firm innovation is also influenced by the size of the market. (Bhide, 1991; Christensen and Bower, 1996). – Katila and Shane (2005)	MKT_SIZE = LN (Industry Sales)	COMPUSTAT
Market growth	Higher previous growth rate indicates higher future growth prospects Rao et al. (2004), others	MKT_GWTH = % growth in industry sales over 1 year	COMPUSTAT
Organizational Slack	'Cushion of excess resources that the firm can use in a discretionary manner (Bourgeois, 1981). (Sharfman et al., 1988). – Fang et al. (2008)	ORG_SLACK = Working capital/Total assets	COMPUSTAT
Capital Intensity	Control for assets	CAPITAL_INT = Fixed Assets (Plant, Property & Equipment)/Total Assets	COMPUSTAT

Financial Leverage	'The extent to which a firm uses debt to finance its assets (Jensen and Meckling, 1976). – Srinivasan (2006)	FIN_LEV = Long term debt/Total assets	COMPUSTAT
Firm Size	Control for size	FIRM_SIZE = LN (# of employees)	COMPUSTAT
Working Capital	Control for working capital	WORK_CAP = Working capital/Total Assets	COMPUSTAT
Year Dummy	Control for Year specific effects	YEAR	
Industry Dummy	Control for industry specific effects	INDUSTRY	COMPUSTAT

3.4. Model

We test our hypotheses using two models. We use the count of design innovations as the dependent variable in our first model (see equations 1 and 2 below), and the count of utility innovations as the dependent variable in our second model (see equations 3 and 4 below). Given that a number of firms in our sample do not innovate on design, or choose to file patents for design, we have an inflated number of zeroes in our data. Therefore, as recommended by Cameron and Trivedi (2013), a raw count of design patents accounting for inflated zero values is an appropriate dependent variable. Correspondingly, we use a Zero-inflated Poisson regression to model the effects of the antecedent variable on design innovation. In our second model, given that utility patents in our dataset outnumber design patent (see Table 1), and given that they are never zero filings, we utilize the recommended random effects Poisson model. We organized our data in a panel format, tracking the number of new design patents that were filed for by firms between 1995 and 2004. In order to account for the endogeneity of patents, we utilize lagged independent variables (Rao et al., 2004; Sorescu and Spanjol, 2008; Morgan and Rego, 2006; Luo and Bhattacharya, 2006; Anderson et al., 2004).

$$DES\_INNOV_{it} = \alpha_0 + \alpha_1 RD\_INT_{i(t-1)} + \alpha_2 MKT\_INT_{i(t-1)} + \alpha_3 MKT\_SIZE_{i(t-1)} + \alpha_4 MKT\_GWTH_{i(t-1)} + \alpha_5 ORG\_SLACK_{i(t-1)} + \alpha_6 CAPITAL\_INT_{i(t-1)} + \alpha_7 FIN\_LEV_{i(t-1)} + \alpha_8 FIRM\_SIZE_{i(t-1)} + \alpha_9 WORK\_CAP_{i(t-1)} + \alpha_{10n} DES\_INNOV_{it} = \alpha_0 + \alpha_1 RD\_INT_{i(t-1)} + \alpha_2 MKT\_INT_{i(t-1)} + \alpha_3 MKT\_SIZE_{i(t-1)} + \alpha_4 MKT\_GWTH_{i(t-1)} + \alpha_5 ORG\_SLACK_{i(t-1)} + \alpha_6 CAPITAL\_INT_{i(t-1)} + \alpha_7 FIN\_LEV_{i(t-1)} + \alpha_8 FIRM\_SIZE_{i(t-1)} + \alpha_9 WORK\_CAP_{i(t-1)} + \alpha_{10n} \sum_{n=1}^{9} YEARn + \alpha_{11m} \sum_{n=1}^{2} INDUSTRYm \tag{1}$$

$$DES\_INNOV_{it} = \alpha_0 + \alpha_1 RD\_INT_{i(t-1)} + \alpha_2 MKT\_INT_{i(t-1)} + \alpha_3 MKT\_SIZE_{i(t-1)} + \alpha_4 MKT\_GWTH_{i(t-1)} + \alpha_5 ORG\_SLACK_{i(t-1)} + \alpha_6 CAPITAL\_INT_{i(t-1)} + \alpha_7 FIN\_LEV_{i(t-1)} + \alpha_8 FIRM\_SIZE_{i(t-1)} + \alpha_9 WORK\_CAP_{i(t-1)} + \alpha_{10} MKT\_GWTH_{i(t-1)} * MKT\_EXP_{i(t-1)} + \alpha_{11} MKT\_GWTH_{i(t-1)} * RD\_EXP_{i(t-1)} + \alpha_{12n} \sum_{n=1}^{9} YEARn + \alpha_{13m} \sum_{n=1}^{2} INDUSTRYm \tag{2}$$

$$TECH\_INNOV_{it} = \beta_0 + \alpha_1 RD\_INT_{i(t-1)} + \beta_2 MKT\_INT_{i(t-1)} + \beta\beta_3 MKT\_SIZE_{i(t-1)} + \beta_4 MKT\_GWTH_{i(t-1)} + \beta_5 ORG\_SLACK_{i(t-1)} +) + \beta_6 CAPITAL\_INT_{i(t-1)} + \beta_7 FIN\_LEV_{i(t-1)} + \beta_8 FIRM\_SIZE_{i(t-1)} + \beta_9 WORK\_CAP_{i(t-1)} + \beta_{10n} \sum_{n=1}^{9} YEARn + \beta_{11m} \sum_{n=1}^{2} INDUSTRYm \tag{3}$$

$$TECH\_INNOV_{it} = \beta_0 + \alpha_1 RD\_INT_{i(t-1)} + \beta_2 MKT\_INT_{i(t-1)} + \beta\beta_3 MKT\_SIZE_{i(t-1)} + \beta_4 MKT\_GWTH_{i(t-1)} + \beta_5 ORG\_SLACK_{i(t-1)} +) + \beta_6 CAPITAL\_INT_{i(t-1)} + \beta_7 FIN\_LEV_{i(t-1)} + \beta_8 FIRM\_SIZE_{i(t-1)} + \beta_9 WORK\_CAP_{i(t-1)} + + \beta_{10} MKT\_GWTH_{i(t-1)} * MKT\_EXP_{i(t-1)} + \beta_{11} MKT\_GWTH_{i(t-1)} * RD\_EXP_{i(t-1)} + \beta_{12n} \sum_{n=1}^{9} YEARn + \beta_{13m} \sum_{n=1}^{2} INDUSTRYm \tag{4}$$

4. Results and discussion

Table 4 presents a summary of the data including correlations. Of particular note is the high value of the standard deviation for design innovations. This is due to the zero-inflated nature of the count data. However, as discussed earlier, this has been accounted for by utilizing a Zero-inflated Poisson model, as recommended by Cameron and Trivedi (2013). While the correlation between design innovation and technology is high, we do not use these in the same model and hence does not pose a concern. We also checked the variance inflation factors (VIF), which were all less than 5, with the highest at 2.6. Thus, multicollinearity is not a problem in our data.

Table 4. Correlations, Means and Standard Deviations.

	Mean	**Std. dev**	**DES_INN**	**TECH_INN**	**RD_INT**	**MKT_INT**	**ORG_SLACK**	**CAP_INT**	**MKT_SIZE**	**MKT_GWTH**	**FIN_LEV**	**FIRM_SIZE**	**WORK_CAP**
DES_INN	5.29	21.14	1.00										
TECH_INN	94.47	253.30	0.67	1.00									
RD_INT	0.12	0.21	−0.06	−0.09	1.00								
MKT_INT	0.38	0.30	−0.11	−0.18	0.66	1.00							
ORG_SLACK	0.05	0.22	0.04	0.05	−0.57	−0.40	1.00						
CAP_INT	0.34	0.19	0.20	0.28	0.11	0.17	−0.02	1.00					
MKT_SIZE	2.51	0.06	−0.12	0.06	0.09	0.00	−0.02	−0.17	1.00				
MKT_GWTH	6.45	10.26	0.05	0.00	−0.01	0.02	0.12	0.04	−0.17	1.00			
FIN_LEV	0.12	0.39	0.04	0.09	0.00	−0.07	−0.11	0.12	−0.09	0.03	1.00		
FIRM_SIZE	1.25	2.19	0.33	0.54	−0.25	−0.46	0.22	0.33	0.07	−0.02	0.14	1.00	
WORK_CAP	0.31	0.87	−0.15	−0.24	−0.05	−0.05	0.21	−0.32	−0.04	0.02	−0.27	−0.46	1.00

Table 5 presents the results of our analysis examining the drivers of design innovations. Models 1 and 2 examine the drivers of design innovations, while models 3 and 4 examine the drivers of technology innovations. Model 1 is our base model for design innovations, while model 2 accounts for interactions of R&D and marketing spending on market growth. We hypothesized that investments in marketing and sales would be positively associated with design innovations, and not with technology innovations. While marketing expenditure has no direct relationship on design innovations in our base model, our second model where interactions with market growth are accounted for shows a significant relationship. The relationship between marketing expenses and technology innovations are, however, negative and significant in both models 3 and 4. Consistent with prior literature (Mizik and Jacobson, 2003; March, 1991), investing in marketing activities seems to take away from technology innovations. This suggests that there is a trade-off between the kinds of resources a firm chooses to invest in. In sum, these results generally show support for H1.

Table 5. Results of Analysis.

	Design Innovations		**Technology Innovations**	
	Model 1	**Model 2**	**Model 3**	**Model 4**
Model Variables				
R&D Intensity	4.735***	4.229***	2.500***	1.498***

Mkt Intensity	0.017*	0.581**	−0.966***	−0.779***
Mkt. Size	−35.108***	−39.838***	3.658***	5.322***
Mkt Growth	0.016***	0.053***	0.008***	0.002*
Mkt*Mkt Growth		−0.173***		−0.016**
R&D*Mkt Growth		0.126***		0.115**
Control Variables				
Fin Leverage	−0.840***	−0.718***	−1.524***	−1.56***
Firm Size	0.615***	0.613***	0.122***	0.122***
Cap. Intensity	−0.292**	−0.356***	1.992***	1.971***
Org. Slack	1.368***	1.509***	0.717***	0.627***
Work. Capital	0.519**	0.721**	−0.297***	−0.329**

* p <.05;

** p <.01;

*** p <.001.

We hypothesized that investments in research and development would be positively related to technology innovations. The results show that, consistent with our expectations, R&D investments are positively associated with higher rates of technology innovations, supporting H2. However, R&D was also positively related to design innovations, an unexpected result that could be a reflection of the internally focused nature of R&D investments and how these investments help facilitate communication between designers in highly complex projects (Salter and Gann, 2003). We believe it most interesting to consider these sets of results in tandem.

The results showed that design innovations are more prevalent in small, but growing markets, as evidenced by the large and negative coefficient on the market size variable and positive coefficient of the market growth variable, supporting H3b and H4. This finding indicates that in the early stages of the lifecycle, firms consider design an important driver of adoption. Given the relatively lower capital intensity required for design innovations (as compared to technology investments), to enter and operate in smaller markets, we believe that market growth serves as a proxy for potential market size. On the other hand, in larger markets, technology innovations appear to be more prevalent, supporting H3a. This is demonstrated by the positive coefficients on market size, in both models 3 and 4. Larger markets typically have greater diversity of products offered by more competitors and the effort to differentiate arises from functional and technology innovations, as compared to design innovations. In support of H4, both types of innovation were associated with high-growth markets.

H5a suggested that higher market growth would decrease the positive influence of marketing/sales spending on design innovations. We found support for this hypothesis. H5b proposed that higher market growth would have a positive effect, increasing the positive influence of R&D spending on technology innovations. This hypothesis was also supported. Interestingly though, differential effects across innovation types were not found in H5a and H5b. Regardless of the innovation type being pursued, market growth diminished the effectiveness of marketing/sales spending yet increased the efficacy of R&D investments.

The effects of our control variables are mostly as expected. First, higher levels of debt, as measured by the leverage of the firm were associated with fewer of both design and technological innovations. This relationship is as expected, since when the firm takes on higher than average levels of debt, these monies may be allocated to keeping operations running, rather than in innovation. Correspondingly, we find that firms invest in both design and utility innovations when there is slack resource within the respective organizations. Interestingly, however, we observe that the working capital ratio is positively associated with design innovations, whereas it is negatively associated with technology innovations. We are cautious in our interpretation of this often-used ratio, since smaller values of the working capital ratio could result from higher values of total assets. In other words, we argued earlier that technology innovations would be associated with firms that have greater assets. Therefore, though the value of the numerator (current assets – current liabilities) is positive, the ratio could still be small. We also observe that technology innovations are associated with a greater investment in capital (plant property and equipment). On the other hand, design innovations are associated with less capital investment. This supports our argument that design innovations take far less resources, as compared to technological innovations.

Reflecting on the results of the hypothesis testing, two major themes emerged from this study:

4.1. Theme #1: internal vs. external focus

The results show that in the industries included in the study, R&D spending is positively related to both design and utility patent production. While this is not a surprising result in the latter case, it is interesting to see this connection between R&D investment and design. This suggests that technology and design output may be intertwined. For example, advances in computer component miniaturization may lead to thinner and more unique case designs, which earn a design patent. So, this internal focus on research & development seems to fuel efforts towards both design and utility patents.

For a firm taking what might be called an external focus, an emphasis on sales and marketing creates more differential effects on patent outcomes. The results here show that this marketing/sales focus is negatively associated with the development of utility patents. This appears to suggest that firms pursuing utility patents are focused on science-driven technological advancement which, if developed to the point where a patent is earned, may not require an intense marketing and sales effort to be a success. It is likely that these, by definition, highly differentiated products will largely sell through word-of-mouth and other channels in the scientific community. For design patents, we found support in model 2 for a positive relationship between marketing/sales investments and design patent output. Combined, this evidence suggests that an environment conducive to design innovations is more complex than a straight technology-focused effort, as design innovations are driven by both marketing/sales and R&D investments. This dual focus seems fairly rare in corporate strategic orientations, perhaps beginning to suggest why design patents are less common than their utility counterparts.

4.2. Theme #2: responding to environmental factors

As expected, in the industries included in the study, the competitive pressures of high-growth markets tend to lead to higher rates of both types of patents. However, market size showed an interesting differential effect on patent production. In larger markets, utility patents were more prevalent, perhaps suggesting that they are a key differentiating point in situations where customers may have more choice. In smaller markets, however, design patents were more likely. This suggests that in niche markets, a low-tech, creative design may be enough to achieve a meaningful level of customer appeal and perhaps some separation from the competition.

We explored these relationships more deeply by considering the interactions between Marketing/Sales or R&D spending and patent output. The results (see Table 5) show that in considering R&D spending, its positive effect on both forms of patent production is accentuated in a high market growth environment. However, the picture surrounding marketing/sales spending is more complicated. The results suggest that for design patents, the generally positive relationship between marketing/sales expenditures and patent output is hurt in higher growth markets. This may be explained by the idea that faster growing markets are naturally more turbulent, making any marketing effort more difficult and less effective. Regarding utility patents, however, the results suggest that the generally negative relationship between marketing/sales spending and patent output is mitigated in higher growth markets. In other words, as the market growth rate increases the negative effect of marketing/sales on utility patent output is reduced. In sum, these results suggest that design may be a more powerful strategic weapon in smaller but growing markets, while a shift from a marketing focus to a more traditional technology/R&D focus may be appropriate at some tipping point in the maturation of the market.

This is encouraging for developing companies since the capital investment required for the pursuit of innovative designs is likely less than that needed for advancements in the basic science to drive utility patents.

5. Conclusion

5.1. Limitations

Research investigating innovation typically utilizes one of two methods. The first, directly measuring innovation, is difficult to administer and manage and is cost prohibitive because it requires gathering data from trade journals or directly from firms (Archibugi and Pianta, 1996). Therefore, most research relies on the second method, measures of patent activity as a proxy for innovation. This method has been found a valid measure (Acs et al., 2002; Jaffe et al., 1998; Acs and Audretsch, 1989), though criticized as imperfect as it neglects to take into account the impact that patents have on future innovations (Trajtenberg, 1990; Pakes and Griliches, 1980). Though many research studies use patent activity as a proxy for innovation activity, it is important to acknowledge the limitations of this connection. Patents should not be seen as a firm's sole evidence of innovation. Many firms engage in innovation activities that never result in patents and most patents are never commercialized (Walker, 2015). In fact, Brouwer and Kleinknect (1999) show that smaller innovators have a lower probability of applying for patents, but those that do have more patent applications than larger firms. This demonstrates that a firm's propensity to patent is not solely reflective of its innovation activities. Thus, patent counts may be an imperfect measure of innovation activity, but it is the most useful and efficient method we have.

Another important limitation to consider is the criteria for receiving a design patent. Design patents do not overlap with utility patents and thus do not describe how an innovation functions, but design patents do describe the innovation's unique, distinctive shape or appearance (USPTO, 2011). These criteria are arguably superficial and do not capture some of the more sophisticated principles of design thinking. For example, a unique shape may be granted a design patent, but the shape may only hint at the design's ability to create an exceptional user experience for the consumer. In other words, a creatively designed handle may be patentable, but the ergonomics underlying the design decisions are not. Thus, design patent counts can be used as a measure of innovation activity, but they do not capture the underlying philosophy that a firm may use to direct innovation activities, which may be another contributing factor to its success. Steen et al. (2014), for instance, argue that design thinking projects are complex and steeped in uncertainty and that such projects might even require an organization to develop an ability to draw ideas and knowledge from multiple departments and other organizations.

Another limitation of the study is that specific marketing expenses are unavailable for firms in our data set. Similarly, since firms are not required to report advertising expenses (since 1994), advertising expenses, which are only a subset of marketing expenses are sparse. While SG&A expenses are a proxy measure for marketing expenses, is utilized in literature and significantly correlated (.76) with advertising expenses (a subset of marketing expenses), in our dataset, it does not fully capture true marketing expenses.

Finally, the results of this study may be industry specific. For instance, the furniture industry (Gemser and Leenders, 2001; Gemser and Wijnberg, 2001), may be seen as an industry where design (as opposed to technology) is more critical to firm performance, as compared to the industries in our sample. Gemser and Leenders (2001) also find that in the Dutch furniture industry, corporate reputation is a deterrent to competitive imitation, the foundational function of intellectual property. We do not make these observations with our sample.

5.2. Future research

To date, the subject of design innovation has received little attention in the management and marketing literatures. It is our hope that this study will be the jumping off point for further exploration of this topic and we offer a few suggestions for investigation into related lines of inquiry.

One area that needs further attention are the organizational climates that breed design and technology innovations. Applying both the system-structural (Silverman, 1970) and strategic choice (Child, 1972) theories of organization can help us understand the innovative capacity of firms and how their organizational climates might lead to one form of innovation over the other. Additionally, organizational leadership styles (Eagly et al., 2003) could be a possible driver of different types of innovation, especially as they relate to knowledge management (Politis, 2001).

Another area worthy of attention focuses specifically on the differing performance outcomes associated with design and technology innovations. Differential outcomes could be a by-product of a firm's incremental or radical innovation orientation (Tushman and Romanelli, 1985); future research could explore whether design or technology innovations are more associated with either of these orientations. A firm geared for incremental innovation might focus on lower risk projects where the reward is near term such as a design innovation where the obstacles are relatively small. A firm geared for radical innovation might take bolder technology innovation moves in the marketplace with less regard for risk and they might be the first to develop new products or technologies that would obsolete their own offerings.

Being an early work on the drivers of design activity that relies on design and utility patents as a measure, we chose to examine the phenomenon during a period of economic stability. The influence of economic swings on the nature of design and technology innovation and the corresponding choices that firms make is an interesting topic for follow up work. Future research could also look at a subset of firms that have more direct measures of marketing expenses.

Finally, future research should consider the longevity or "staying power" of the performance benefits these forms of innovation deliver. A longitudinal assessment of innovative firms would shed light on whether design and technology innovations make lasting impacts and what role firm culture might play.

This research has shed light on a form of innovation output, design patents, that is new to innovation research yet, based on anecdotal evidence from practice, seems to be growing in strategic significance. While not equivalent, this project also represents a more scientific assessment of popular managerial trends such as design thinking. By establishing that design innovation is a unique and different phenomenon with different and available outcome measures, we hope to stimulate a new stream of quantitative, design-based research.

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Footnotes

[1] https://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm

[2] http://www.uspto.gov/patents/

[3] http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm

[4] NAICS – North American Industry Classification System is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. (https://www.census.gov/eos/www/naics/).