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How Do Young Firms Manage Product Portfolio Complexity? The Role of Absorptive Capacity and Ambidexterity

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Abstract:

Building a complex portfolio of products can be beneficial for young firms due to increased sales growth and competitiveness. Yet, the benefits from product portfolio complexity (PPC) are often outweighed by rising costs, leading to an inverted U-shaped relationship between PPC and performance. Recent research has called for an increased understanding of how firms are able to better manage higher levels of PPC. We suggest that absorptive capacity and ambidexterity are vital to enhancing the benefits and mitigating the costs of increasing PPC. Using a sample of 215 young high technology firms, we find support for positive moderating effects of absorptive capacity and ambidexterity on the inverted U-shaped relationship between PPC and firm performance.

Keywords: product portfolio complexity, absorptive capacity, ambidexterity, technology, organizational learning

INTRODUCTION

In technology-based industries, firms have become increasingly reliant on product development to compete in the constantly evolving global marketplace. Many young technology firms are particularly motivated to develop diverse portfolios of products with multiple features and variants to increase sales growth and competitiveness (Rothaermel and Deeds, 2004) and, thereby, improve their likelihood of survival (Dowell and Swaminathan, 2006). Building a diverse product portfolio helps mitigate the risk of solely relying on a few signature products and also enables young firms to better withstand uncertainty and technological change in their environment (Day, 2007). An unintentional consequence of building such a vast array of products is an increased state of complexity or information processing difficulty associated with the management of product portfolios (Closs *et al.*, 2008). As diverse product portfolios are created, managers experience increased coordination and communication costs (Chandy *et al.*, 2006). At some point, the costs of product portfolio complexity (PPC) can outweigh the benefits (Closs *et al.*, 2008; Thompson, Hamilton, and Rust, 2005), resulting in an inverted U-shaped relationship between PPC and firm performance. The economies of scale and scope experienced with increasing product diversity eventually diminish as strategic responses resulting from increased commercialization capabilities become inefficient. Due to the negative trade-offs that occur at higher levels of PPC, some researchers suggest that less PPC is better (e.g., Quelch and Kenny, 1994). Yet, given the varying time necessary to materialize commercialization efforts and the multifaceted nature of product development efforts, it is difficult to identify, let alone capitalize on, an optimal level of PPC (Fisher and Ittner, 1999). Recent research instead calls for an increased understanding on how firms can better manage higher levels of PPC (Closs *et al.*, 2008; Kim and Wilemon, 2009).

Through a robust set of case studies, Closs and colleagues (2008) identified three important competencies related to strategy, governance, and support systems that enable firms to manage PPC. While insightful, the cases center on large existing companies. Compared to large firms, young firms differ in their heavy reliance on external sources of knowledge. As noted by McGrath and MacMillan (1995: 44), young firms have a ‘high ratio of assumption to knowledge’ and are, therefore, more motivated to glean information from the external environment to counteract their assumptions or guesswork. Thus, we introduce the importance of learning and the appropriation of external knowledge as a fourth, systems-based response, to managing PPC. Cohen and Levinthal (1989) acknowledge the dual roles of both learning and appropriation of knowledge for the new product development process, pointing out that research and development (R&D) require the acquisition, assimilation, transformation, and exploitation of external knowledge (Zahra and George, 2002). While absorptive capacity reflects the ability of a young firm to value and integrate external knowledge for managing PPC, ambidexterity helps further structure how the knowledge is to be appropriated and used in context of limited resources and routines in young firms. Both absorptive capacity and ambidexterity are critical to minimizing the adverse costs of PPC while maximizing the benefits.

Focusing on the effects of organizational learning in increasing the benefits of PPC and mitigating the costs of high PPC is important for several reasons. First, although prior work acknowledges the presence of trade-offs, very limited, if any, *empirical* evidence exists on how young firms can increase returns from PPC and mitigate the effects of increased communication and coordination costs and lower profitability. Second, despite reducing returns from increased PPC, there is limited *theoretical* exposition on how young firms can better manage PPC to further leverage their product portfolios. The need for researchers to better understand how PPC can be managed, especially in young firms, has been recognized and called for (Closs *et al.*, 2008). Thus, we offer insight as to how organizational learning mechanisms mitigate communication costs and increased cognitive load in young firms with limited routines in directing complex portfolios (Rothaermel, Hitt, and Jobe, 2006) and how they increase coordination within the firm and across supply chain members. Such mechanisms can also enhance the benefits of increased PPC by identifying new opportunities (Cohen and Levinthal, 1990) and helping ensure a long-term revenue stream (March, 1991). Third, our focus on young firms offers a contribution to the entrepreneurship literature, as we demonstrate how young firms can maximize PPC to help ensure survival and competitive advantage through increased performance. Given their limited resources, managing PPC is especially important for many young firms entering technology industries that are increasingly complex and dynamic in nature.

The contribution of this study also extends to the absorptive capacity and ambidexterity literatures. Although the role of absorptive capacity in increasing firm performance has been frequently highlighted in the literature (e.g., Lane, Salk, and Lyles, 2001), much less research has focused on the contingent role of internal firm characteristics, especially those relating to firms' product portfolios. Given that absorptive capacity and the product development process are closely related (Stock, Greis, and Fischer, 2001), it appears likely that absorptive capacity could have fairly significant implications for young technology firms' management of PPC. The underlying premise of ambidexterity suggests that firms capable of managing both exploratory and exploitative activities will be able to achieve superior performance (Rothaermel and Deeds, 2004; Tushman and O'Reilly, 1996). However, the few empirical tests of such relationships are not entirely consistent (Raisch and Birkinshaw, 2008). As such, in this study, we respond to calls in the literature to further understand this relationship (Raisch and Birkinshaw, 2008; Simsek, 2009) and propose that the coexistence of PPC and ambidexterity enhances firm performance.

THEORY AND HYPOTHESES

Closs and colleagues (2008: 591) define PPC as the ‘state of processing difficulty that results from a multiplicity of, and relatedness among, product architectural design elements.’ Thus, not only does the volume of a firm's product offerings create complexity but so do the diversity and interlinkages in the product architecture. It is important to note that firms do not necessarily set out to achieve such a state of complexity; rather, it is a consequence of external product-market competition and internal product development decisions that add to the volume and diversity of their portfolios. Nonetheless, firms vary significantly in their product development strategies and, consequently, the state of complexity achieved.

Benefits of product portfolio complexity

There are many benefits to building a complex portfolio of products that can be especially attractive to young firms. Perhaps the biggest draw is the ability to increase sales. Due to their limited history, the initial sales obtained by young firms can signal their likelihood for success and can help them reinvest in developing resources and capabilities (Fombrun and Shanley, 1990). Increased sales can also be used to build up cash reserves, thereby offsetting the challenges stemming from limited resources and legitimacy (Hannan and Freeman, 1984).

Building PPC further contributes to a young firm's overall competitiveness (Barney, 1991). As a firm builds and develops a more complex portfolio of products, it becomes increasingly difficult for competitors to understand and replicate or substitute its competitive advantage. This is largely due to the complex product architecture linkages resulting in a multifaceted and ambiguous bundle of commercialization capabilities. This combinative capability, which joins existing knowledge, tasks, tools, and processes, is also key to generating new product innovations (Kogut and Zander, 1992). Younger firms are typically more innovative than older firms due to their flexibility and responsiveness (Chen and Hambrick, 1995; King, Covin, and Hegarty, 2003). Thus, building PPC enables young firms to more effectively compete with their larger counterparts.

Changes in customer demands can also eliminate the need for existing products while creating opportunities for new products (Schumpeter, 1934). Greater PPC strengthens a firm's technical core and further acts as a buffer by enabling a young firm to better withstand and respond to technological changes and uncertainty in the external environment (Kim and Wilemon, 2009). Complex product portfolios offer more opportunities to develop radical products to meet demand and technological and competitive uncertainty (Sorescu, Chandy, and Prabhu, 2003). Commercialization capabilities resulting from PPC help firms act first to capture a larger market share (Mascarenhas, 1992), establish buyer preferences (Carpenter and Nakamoto, 1989), and increase switching costs. In the same vein, PPC increases strategic real options (Kogut and Kulatilaka, 2001), thereby helping young firms avoid a severe impact should a single product fail or become obsolete.

Lastly, complex product portfolios result in synergies and shared learning within and outside the firm. Internal knowledge spillovers can subsequently lead to greater economies of scale and scope in developing, producing, marketing, and distributing products while simultaneously creating product diversity (Kotha, 1995). In other words, PPC could reduce knowledge integration and enhance efficiency while maintaining higher levels of product variety. Such a capability further fuels investments in the development and production of new products (Brown and Eisenhardt, 1997).

Costs of product portfolio complexity

In spite of the many benefits of PPC, excessive investment in PPC could be detrimental. Perhaps the most evident drawback of overinvesting in PPC relates to the scale of innovation activities required to develop complex portfolios of products with multiple features and variants. Such activities typically require a large financial investment (Johnson and Kirchain, 2011) and also entail an element of risk. Although failed projects can contribute to the development of learning and innovative capabilities (Elmquist and Le Masson, 2009), not all R&D endeavors result in success (Choi and Ahn, 2010; King, Slotegraaf, and Kesner, 2008). Young firms typically have limited tangible and intangible resources to invest, increasing negative impacts of a failed innovation effort on survival.

Significant coordination costs can also arise alongside PPC. Due to their limited operating history, young firms typically lack or are in the process of developing structured routines and procedures (Stinchcombe, 1965). While a lack of formalization can contribute to the development of a larger and more complex product portfolio in young and flexible firms (Chen and Hambrick, 1995), the role ambiguity that commonly accompanies limited formalization can serve as a barrier or constraint on the coordination of an increasingly complex portfolio. Role ambiguity increases conflict among marketing, design, and manufacturing functions, as well as divergence in time frames, goals, and assumptions (Fisher, Ramdas, and Ulrich, 1999). Role ambiguity also contributes to coordination costs through related inefficiencies. As argued by Sine, Mitsuhashi, and Kirsch (2006: 123), young firms that 'lack clear boundaries of responsibility will be forced to rely upon decision making by consensus, thereby decreasing the speed and increasing the cost of any particular decision.'

In addition, increasing levels of PPC can take a significant cognitive toll on the management team of a young firm (Rothaermel *et al.*, 2006). Managers may experience information overload due to growing portfolios that require the coordination and optimization of internal resource allocations while meeting market demands. In these situations, managers are more likely to engage in suboptimal behavior relying on biases and heuristics to make product architecture related decisions, which could result in the introduction of new products that may not essentially increase firm value (Leenders, Van Engelen, and Kratzer, 2007). Cognitive overload is especially detrimental to managers in young firms due to the liabilities associated with newness. As explained by Simon (1955), if a manager finds it difficult to discover alternatives (in this case, due to information overload and a reduced attention span resulting from focusing on too many projects), his or her ambition or desire to continue searching for alternatives decreases. The result is that the manager will take the first satisfactory alternative without fully examining all of the alternatives available. In this sense, satisficing behavior is substituted for optimizing behavior, and the result could be harmful or even fatal for young firms if the most promising opportunities are overlooked and resources are not allocated to the most effective commercialization efforts.

Benefits and costs of product portfolio complexity

Overall, increased PPC could help young firms develop an effective response to technological change and uncertainty in the environment, while increasing product diversification and competitiveness. However, such gains may diminish at higher levels of PPC due to increased coordination and communication costs in managing tangible and intangible resources and capabilities. The existence of trade-offs have also been recognized in other strategic areas of the firm, including the level of internationalization (Geringer, Beamish, and daCosta, 1989), the extent of geographic clustering (Folta, Cooper, and Baik, 2006), and product diversification (Qian, 2002). In each case, there comes a point when costs outweigh the benefits. Similarly, we propose that although increased PPC results in increased performance, after some point, there may be a negative trade-off due to the rising costs associated with PPC (Quelch and Kenny, 1994; Sievänen, Suomala, and Paranko, 2004; Thompson *et al.*, 2005). Thus, we propose the following:

Hypothesis 1: There will be an inverted U-shaped relationship between PPC and firm performance where PPC is positively related to firm performance to a point, after which it becomes negative.

Organizational learning and product portfolio complexity

Given that it can take varying amounts of time to realize the implications of new product introductions and (or) managerial decisions and because these processes are multifaceted in nature, it is often difficult to identify and capitalize on an optimal level of PPC (Fisher and Ittner, 1999). Accordingly, researchers have begun to highlight the importance of managing PPC instead (Closs *et al.*, 2008; Kim and Wilemon, 2009). Through a robust set of case studies centering on large firms with rather complex product portfolios, Closs and colleagues (2008) identified three important competencies related to strategy, governance, and support systems. Building upon their findings, we introduce the importance of learning and the appropriation of external knowledge as a fourth, systems-based response to managing complexity. While absorptive capacity reflects a young firm's ability to value and integrate knowledge for learning, ambidexterity is also important because it helps further define how the knowledge is to be appropriated and used. Extending an earlier proposition by Priem and Butler (2001), the value of PPC as a resource is deemed to be variable. Venture-specific conditions such as absorptive capacity or ambidexterity could therefore affect the degree to which different ventures derive varying value from the same levels of PPC.

Moderating role of absorptive capacity

The ability of a firm to recognize, assimilate, and apply external knowledge to commercial ends (Cohen and Levinthal, 1990; Zahra and George, 2002)—otherwise termed its absorptive capacity—is important to managing a highly complex product portfolio. Absorptive capacity helps enhance new product development while simultaneously reducing the coordination costs that accompany PPC. Foremost, absorptive capacity facilitates the identification of new and highly valuable product opportunities, contributing to the much needed sales for a young firm. Firms with high absorptive capacity have embedded routines in tasks, tools, processes, and people to analyze and absorb external knowledge to meet market needs. Young technology firms specifically rely on diverse knowledge sources, such as knowledge from stakeholders, supply chain members, alliances, and the general public domain. When there are changes in the external environment, firms with high PPC and absorptive capacity can quickly recognize new opportunities due to their systematic knowledge conversion processes and alertness (Boal and Hooijberg, 2000). New knowledge combinations are subsequently likely to be highly innovative and responsive to current market needs, resulting in the identification of new product opportunities that have high potential for success.

Absorptive capacity can also help reduce the coordination costs that go along with higher levels of PPC through social integration mechanisms. One of the central components of effective absorptive capability is the necessity of connectedness and shared meanings at the firm level (Todorova and Durisin, 2007). Such social integration mechanisms are an integral part of absorptive capacity because they facilitate knowledge combinations and distribution (Vega-Jurado, Gutierrez-Gracia, and Fernandez-de-Lucio, 2008). While the implications of the social integration mechanisms that accompany absorptive capacity have not yet been applied to the management of PPC, a closer look at the literature suggests there are many benefits to be gleaned. As noted by Smith and colleagues (1994), such social integration mechanisms can enhance the coordination of functional areas within the firm. Social integration helps create shared identity and mission (Hedlund, 1994), which can enhance trust and minimize conflicts. Such dynamics also increase knowledge sharing (Huang, 2009) and problem solving (Rico *et al.*, 2007) while reducing cognitive load (Kang, Yang, and Rowley, 2006)—all of which are beneficial to young firms attempting to manage complex portfolios of products.

With increased complexity, it was previously acknowledged that managers could resort to satisficing and selecting suboptimal opportunities to pursue (Leenders *et al.*, 2007). However, due to knowledge conversion routines across the firm associated with absorptive capacity, the availability of selective and relevant information increases comprehensive decision making and helps manage cognitive load (Simon, 1955). Thus, we posit:

> *Hypothesis 2: Absorptive capacity moderates the inverted U-shaped relationship between PPC and firm performance such that at high levels of PPC, firms high in absorptive capacity outperform firms low in absorptive capacity*.

Moderating role of ambidexterity

While absorbing external knowledge is central to mitigating trade-offs at higher levels of PPC, managing a balance of innovations through ambidexterity is also important to ensure that the knowledge is appropriated in the best manner for a young firm that is also managing liabilities of newness and smallness. Within the technological innovation context, ambidexterity refers to the simultaneous pursuit of exploitative and explorative activities (Tushman and O'Reilly, 1996). As contrasted by March (1991), incremental innovations represent minor changes to existing products and business processes and are considered to be exploitative. Incremental innovation is less risky and creates greater depth of products, which is necessary for short-term success. Radical innovations, which are exploratory in nature, focus on the needs of emerging customers and the internal business process innovations necessary to meet environmental challenges. Greater risk is involved with radical innovations, but such exploratory initiatives are critical to long-term success. While structural ambidexterity centers on the organizational design and creation of separate subunits that support exploration and exploitation, contextual ambidexterity, in contrast, relies on building a set of systems and processes that support such alignment (Simsek, 2009). As young firms tend to have less formal structures due to their liability of newness (Stinchcombe, 1965), they may lack the ability and resources to create a dual structure. Therefore, contextual ambidexterity is particularly relevant to young firms.

Ambidexterity complements many of the benefits of PPC. In particular, ambidexterity helps young firms take greater advantage of the internal knowledge sharing benefit that can occur with high levels of PPC (Kotha, 1995). As the simultaneous pursuit of exploitation and exploration efforts creates an ability to better absorb new information (Jansen, Van Den Bosch, and Volberda, 2005), learning synergies are enabled while being mutually reinforced (Andriopoulos and Lewis, 2009). A young firm with relatively high PPC can accordingly leverage its ambidexterity to ensure adequate knowledge flow into the product development process while concurrently developing products that promise longer-term success.

To minimize the costs of increasing PPC, ambidexterity provides continuity by helping young firms exploit prior routines and develop new ones (Gibson and Birkinshaw, 2004). Contextual ambidexterity increases managerial ability to manage contradictory goals, increase multitasking, and interact and recombine divergent knowledge sets (Carmeli and Halevi, 2009). These skills can be applied directly to the management of a large and complex product portfolio. Further, by creating an ambidextrous environment where individuals are encouraged and supported in their efforts to pursue both exploitation and exploration throughout the organization, cross-functional conflicts in organizational goals and commitments are minimized (Kleinschmidt and Cooper, 1991). At the same time, ambidexterity limits competency traps by helping young firms focus on both survival through exploitation and growth through exploration.

An additional way that ambidexterity reduces the costs of PPC is by offsetting financial risk in young firms. The creation of a large and complex portfolio can require a sizeable financial investment that can strain a young firm that is attempting to attain legitimacy and may have to frequently look to outside investors for financial support. Ambidexterity helps firms offset the tendency to focus solely on exploitation activities while growing their portfolios (March, 1991). Such an approach subsequently ensures longer-term revenue streams for young firms as highly innovative products in a product portfolio increase performance (Kleinschmidt and Cooper, 1991). While exploitative activities are also important, a tendency solely toward less innovative products signals to customers and stakeholders a firm's inability to commercialize and supply newer products (Song and Motoya-Weiss, 1998). The creation of an ambidextrous environment can thus help put investors at ease if they are able to see highly innovative products being introduced and incorporated in the pipeline in conjunction with the shorter-term profits realized from the exploitative innovations. We accordingly propose:

> *Hypothesis 3: Ambidexterity moderates the inverted U-shaped relationship between PPC and firm performance such that at high levels of PPC, firms that are high in ambidexterity outperform firms that are low in ambidexterity*.

DATA DESCRIPTION

Sampling context

To test our hypotheses, we started with the *Corptech Directory of Technology Companies (Corptech Directory),* published by Corporate Technologies Information Services (Corptech) of Woburn, Massachusetts, to identify high technology manufacturing firms from five Midwestern states within the United States that had 10 to 250 employees and were 10 years old or younger. The *Corptech Directory* is considered a reliable source of private technology firm listings and has been used widely for research on high technology firms (e.g., Sarkar, Echambadi, and Harrison, 2001). In addition to yearly sales and firm size (number of employees) information, the Corptech lists the number of products in different product classes in its directory *Who Makes What?* This allowed us to longitudinally track product introductions over time, which is helpful to measure PPC. Within the entrepreneurship literature, new ventures have been defined as being within their initial six (e.g., Zahra, Ireland, and Hitt, 2000), eight (e.g., Biggadike, 1979), or 10 (e.g., Certo *et al.*, 2001) years of existence. We chose to utilize the 10-year cutoff, as we concluded that such a time frame helped ensure that the firms had time to develop a more or less complex portfolio of products. To balance survey cost and scope, we focused on firms in the U.S. Midwestern states of Illinois, Indiana, Kentucky, Ohio, and Missouri. We were able to identify 1,526 listed firms in the 2009 *Corptech Directory*, representing 30 North American Industry Classification System (NAICS) codes.1

Survey

A pilot survey was conducted with six active entrepreneurship researchers and eight chief executive officers (CEOs) of high technology manufacturing companies in a large Midwestern city. For ambidexterity, we drew on the existing scales of exploration and exploitation from Lubatkin and colleages (2006). Based on the feedback from both the entrepreneurship researchers and CEOs, we included a general definition of innovation, as well as what consisted of radical or incremental innovations. For the absorptive capacity measure, we started with the scale items from Jansen and colleagues (2005). The entrepreneurship researchers provided feedback on adapting the scale from the unit level to the firm level. Based on the revised scale, the CEOs suggested more explanations for several items (Acquisition 1, 3; Assimilation 1; Transformation 1, 6), so we either included examples or provided more clarification for those items. The verbatim items and definitions can be found in the Appendix.

In the context of the current study, CEOs are a relevant respondent group. CEOs play a central role in the strategic and day-to-day management of ventures. They are well informed of ‘strategic issues that explicitly entail organization-wide or external focus’ (Sharfman, 1998: 381). A packet containing our survey, along with a cover letter and prepaid business reply envelope, was sent to the CEO of each firm in September 2009. To enhance typically low response rates among CEOs in the initial mail survey, we informed the respondents that we would donate $20 for every complete survey to a charity of the CEO's choice. Three follow-up reminder emails were sent between October 2009 and January 2010. We received responses from 219 CEOs for a response rate of 14.35 percent. Low response rates (10–15%) are typical for mailed surveys to top executives and are comparable to other studies (Ling *et al.*, 2008). In the final dataset, we excluded four firms with incomplete data. This yielded a final sample of 215 firms. The average CEO age was 38 with 12 years of industry experience.

We tested nonresponse bias for early and late respondents and also the mean responses of respondents and nonrespondents in terms of age, sales revenues, firm size (number of employees), across 30 NAICS codes, CEO age, CEO gender, and CEO industry work experience. We found no significant differences. Our sampling error was 6.28 percent, which is within acceptable range (Särndal, Swensson, and Wretman, 2003).

Variable operationalizations

Performance

Growth is argued to be a key measure of new venture performance (Gilbert, McDougall, and Audretsch, 2006). Drawing on earlier work (e.g., Baum, Calabrese, and Silverman, 2000), we employed a multidimensional measure that comprised sales growth, employee growth, and operating profit growth. Specifically, we used the geometric mean of these three growth rates to develop the measure of performance (e.g., Hitt and Ireland, 1985). The compounded growth rate for each measure was calculated between 2007, 2008, and 2009. Operating profit growth was self-reported, while sales growth and employee growth were gathered from Dunn and Bradstreet (D&B) and Corptech.

Product portfolio complexity

Traditionally, PPC has been studied in both the marketing and operations management literature. The majority of the operations management research has relied on the case study-based approach (e.g., Closs *et al.*, 2008) where an explicit operationalization of PPC is lacking. Alternatively, in the marketing literature, product offerings have often been used as a proxy for product portfolios (e.g., Biehal and Sheinin, 2007). However, these proxies do not account for a product portfolio's depth and breadth, which contribute to its complexity. Further, the existing measures fail to adjust for the relative levels of industry complexity. Complexity—defined here as the depth and breadth of product offerings—must be considered in relation to the portfolio of products offered by competitors within a firm's industry for two main reasons. First, a venture in a complex industry may need to develop a complex product portfolio to maintain competitive parity. Second, the knowledge spillover and organizational learning literature suggests that innovation routines and capabilities are transferred among competitors (Turner, Mitchell, and Bettis, 2010). Industry competitors may learn from others at a faster pace; therefore, maintaining an average level of PPC may not lead to competitive advantage. By using the relative level of PPC, we assessed whether engaging in increased PPC relative to competitors resulted in greater levels of performance.

We, therefore, operationalized PPCs not only as a depth and breadth measure, but using vector algebra, we also adjusted the resulting measure in the context of other industry firms' PPC. The aforementioned CorpTech *Who Makes What?* was used to operationalize PPC, as it provides yearly listings (starting in 1984) by firm, product code, and year for about 50,000 high technology manufacturing establishments. The listings include domestic, foreign-owned, public, and private companies located in the United States. All operating units and subsidiaries are listed under a parent company or holding company. We used unique product listings between 2007, 2008, and 2009 for the firms in our sample. The greater the number of products in a given product class and the more diverse the categories, the greater the complexity. Based on vector algebra, we undertook a pairwise comparison by calculating cosine values between the vectors of two firms across all product classes in an industry (based on Corptech's *Who Makes What?*) and the number of product classes in each industry:

$$sim(f_x, c_j) = \frac{\vec{f_x}, \vec{c_j}}{|\vec{f_x}||\vec{c_j}|} = \frac{\sum_{i=1}^{n} w_{i,x} w_{i,j}}{\sqrt{\sum_{i=1}^{n} w_{i,x}^2}\sqrt{\sum_{i=1}^{n} w_{i,j}^2}}$$

Starting with the focal firm, f_x, the vector of the number of products, (w) in each product category, i, was compared to another firm, c_j, which had a vector of number of products in the same product category. As the angle between the vectors shortens, the cosine value approaches 1 indicating that the vector of products produced by the two firms is more similar. For example, if there are three product classes in an industry, then the vector for the focal firm, f_x, is [0,0,2]—in other words, the focal firm does not produce any products in product categories one and two but produces two products in product category three. Similarly, for a firm, c_1, the vector is [2,3,5]. Under this condition, the cosine value is calculated as $\frac{10}{\sqrt{(4+9+25)(0+0+4)}} = 0.81$. Alternatively, for firm c_2, the vector is [3, 7, 1], and the cosine value between focal firm and c_2 is $\frac{2}{\sqrt{(9+49+1)(0+0+4)}} = 0.13$. Therefore, product portfolio is more similar to c_1 than c_2. We calculated a similarity index for [(f_x, c_1), (f_x, c_2), (f_x, c_3)……(f_x, c_k)], for a total of *K* firms in the industry. We then added the vector to create a total similarity index. To control for industry size and enhance interpretability, we divided the total by *K* firms. When a focal firm had no overlapping product classes with another firm, normalizing the sum of similarity scores further penalized a high dissimilarity score. Continuing from the nature of complexity, the current measure developed an unbiased estimate of the extent to which a firm's products were similar to competitors' at the industry level. The weights in the vector are indicative of the depth, or number of products in a given product class.

Ambidexterity

Because exploration versus exploitation is a general and broad concept, previous studies have suggested a diverse range of operationalizations for ambidexterity, including raw difference scores (algebraic or absolute), profile similarity indices, and polynomial regression (Edwards, 2009). However, drawing on recent debates on operationalizing congruence (Cheung, 2009; Edwards, 2009), we suggest that latent congruence modeling (LCM) is appropriate to operationalize ambidexterity from both a theoretical and statistical standpoint. LCM helps control for measurement errors and test measurement equivalence and provides a more relevant measure of congruence in the context of ambidexterity. Although much of prior ambidexterity research has used scales to measure exploration and exploitation components, statistically such measures assume that measurement errors do not exist. However, LCM controls and removes measurement errors (Cheung, 2009; Edwards, 2009). LCM creates two second-order factors from two components of interest—the mean level of these two variables (called level) and their difference (congruence). In this study, level represents the average of exploration and exploitation, whereas congruence represents similarity in the extent of exploration and exploitation in a venture.

Accordingly, to operationalize ambidexterity using LCM, we started with the self-reported measures of exploration and exploitation from Lubatkin *et al.* (2006), which have six items each (see the Appendix for descriptions, parameter estimates, and item reliabilities). A latent factor for level was created by fixing loadings for exploration and exploitation at 1, and the latent factor for congruence was created by fixing the loadings for exploration and exploitation at 0.5. The two equations can be formally stated as the following:

$$\text{Exploration} = \text{Level} + 0.5^{*}\text{Congruence} \quad (1)$$

$$\text{Exploitation} = \text{Level} - 0.5^{*}\text{Congruence} \quad (2)$$

Adding Equations ((1)) and (2) and rearranging the terms yields the following equation:

$$\text{Level} = |(\text{Exploration} + \text{Exploitation})|/2 \quad (3)$$

Subtracting Equation ((2)) from Equation ((1)) and rearranging the terms yields the following equation:

$$\text{Congruence} = |\text{Exploration} - \text{Exploitation}| \quad (4)$$

By multiplying congruence by a − 1 higher value indicates movement toward ambidexterity.

We tested the latent congruence model using the two second-order latent variables (level and congruence) created by Equations ((3)) and (4) with level serving as a control variable and congruence as a predictor variable. The variance of the residuals and the intercepts for the second-order structural equation modeling equations were constrained to zero. Confirmatory factor analyses were conducted to assess measurement equivalence across the two components of congruence. A higher congruence score implied a greater difference between exploration and exploitation (i.e., dissimilarity rather than similarity). However, greater ambidexterity is intended to imply a smaller difference between exploration and exploitation. For ease of interpretation, we multiplied the scores of congruence by − 1 so that increased balance relates to higher levels of ambidexterity. The results indicated that there was configural equivalence ($\chi^2 = 72.612$; df = 53; p = ns; comparative fit index (CFI) = 0.99; incremental fit index (IFI) = 0.99; root mean square error of approximation (RMSEA) = 0.050), *metric* $\Delta\chi^2 = 1.027$, Δdf = 5, p = ns; CFI = 0.98, IFI = 0.98, RMSEA = 0.052) and *scalar equivalence* ($\Delta\chi^2 = 1.248$, Δdf = 5, p = ns; CFI = 0.99, IFI = 0.99, RMSEA = 0.052) present between exploration and exploitation.

Absorptive capacity

Absorptive capacity was operationalized using an adapted scale originally developed by Jansen *et al.* (2005). The questions were originally based on a business unit level and were modified to fit the context of young firms. Details of the item loadings, reliability, and discriminant validity (based on average variance extracted) are listed in the Appendix and are all at acceptable levels. The second-order factor showed a better fit (χ^2[df] = 294.446 (181); CFI = 0.926; Tucker-Lewis index (TLI) = 0.922; RMSEA = 0.068) than the four correlated factors (χ^2[df] = 320.191 (185); CFI = 0.840; TLI = 0.837; RMSEA = 0.152) or the one-factor model (χ^2[df] = 342.870 (189); CFI = 0.812; TLI = 0.808; RMSEA = 0.193).

Controls

Based on our ambidexterity scale, we controlled for the independent effects of *exploration* and *exploitation*. We controlled for *firm size* (log of number of employees in 2009), and *firm age* was assessed as the number of years from establishment to 2009 as reported in the *Corptech Directory* and cross-referenced with D&B dataset. *Patent depth* (average number of patents in each technological class) and *patent breadth* (total number of technological classes where patents were filed) were drawn from the United States Patent and Trademark Office database. *CEO tenure* was the number of years the CEO was listed in the *Corptech Directory*.

In addition, we incorporated three industry-level measures—*environmental dynamism, environmental complexity,* and *environmental munificence*. All three industry-level measures were assessed each year with moving five-year windows (e.g., 2005–2009) by data obtained from the COMPUSTAT database. Based on Keats and Hitt (1988), we started by identifying net sales and operating income in each of six-digit NAICS codes in the sample. Two regressions were then conducted: (a) a natural logarithm of industry sales on time and (b) a natural logarithm of operating income on time. We took the anti-log of each beta and used the average beta as the measure of munificence. The measure of munificence is the average industry growth rate over the five-year moving window. For environmental dynamism, we took the anti-log of the standard error of the beta in each of the regressions. The average of the resulting standard error is the measure for a given year. Higher standard errors indicate greater environmental discontinuities.

Environmental complexity indicates the trend toward or away from large firm market dominance. As the industry moves away from large firm dominance (lower concentration index), industry complexity increases. Based on Gorssack's (1965) index of dynamic concentration in a six-digit NAICS code, the measure of complexity is the regression coefficient of all firms' terminal year market shares (e.g., market shares for all firms in year 2000) on their shares in the initial year (e.g., market shares for all firms in year 1996). The regression coefficient is obtained as $\beta = \frac{\Sigma x_i y_i}{\Sigma x_i^2}$ where x_i and y_i are deviations in market share from the mean. Under the original specification (Keats and Hitt, 1988), complexity is reverse-scored, so smaller numbers indicate more complex environments. To ease interpretation, we multiplied the coefficient by − 1 so that a higher number indicates greater complexity (Heeley, King, and Covin, 2006).

Finally, we added *manufacturing process* and *organizational structure* as controls.2 Based on Hayes and Wheelwright's product-process matrix (Hayes *et al.*, 2005: 48) and earlier work of Bharadwaj, Bharadwaj, and Bendoly (2007), we classified the high tech firms into four distinct manufacturing processes based on their respective NAICS codes from the *Corptech Directory*: (a) highly standardized continuous flow, (b) high-volume mass production, (c) mid-volume assembly line, (d) mid-volume disconnected line and batch production, or (e) specialized low-volume job shops (reference category).

The organizational structure could facilitate the extent to which PPC is implemented. Based on Sine and colleagues (2006), we used a reflective measure of (a) role formalization, (b) functional specialization, and (c) administrative intensity. Role formalization was the ratio of the number of formalized functions to the number of potential maximum functions. Over a dozen functional areas are included in the *Corptech Directory*. Functional specialization is the average number of functional assignments per founding team member. Administrative specialization is the ratio of the number of executives in the founding team to the total number of employees. The reliability of the measure was acceptable at 0.833.

Construct validity

As illustrated in the Appendix, the proposed measures show adequate convergent and discriminant validity (Anderson and Gerbing, 1988). All item loadings were significant, and reliabilities were above the recommended threshold of 0.7. The average variance extracted for absorptive capacity (0.649), exploration (0.681), and exploitation (0.660) were well above the recommended cutoff of 0.5. Table 1 shows the correlations among the variables. We observed low to moderate levels of correlations. All variance inflation factors were less than 2.25, and the condition index did not exceed 5.20, which further suggests that multicolinearity did not bias estimates (O'Brien, 2007). The results of the confirmatory factor analysis related to ambidexterity and absorptive capacity found: $\chi^2/df = 1.461$; RMSEA = 0.06; standardized root mean square residual = 0.03; TLI = 0.94; BL89 = 0.97, relative noncentrality index = 0.97, CFI = 0.96; Gamma-hat = 0.95; Mc = 0.94. The fit indices met or exceeded the minimum threshold value of 0.90 (Hu and Bentler, 1998).

Table 1. Correlations

	Mean	**SD**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1. Venture growth	0.18	0.13	1.00										
2. PPC	3.01	1.28	0.19	1.00									
3. Ambidexterity - level	2.54	1.01	0.20	0.14	1.00								
4. Ambidexterity- congruence	− 0.34	0.50	0.15	0.12	0.56	1.00							
5. Exploration	2.22	1.19	0.18	0.12	0.29	0.20	1.00						
6. Exploitation	2.56	1.05	0.11	0.11	0.28	0.19	0.09	1.00					
7. Absorptive capacity	2.52	0.74	0.22	0.16	0.22	0.20	0.23	0.27	1.00				
8. Size (#of employees)	53.12	36.98	0.14	0.14	0.14	0.14	0.13	0.22	0.21	1.00			
9. Age	7.07	2.19	0.04	− 0.17	0.11	0.07	0.09	0.11	0.13	0.15	1.00		
10. Environmental dynamism	1.09	0.08	− 0.17	− 0.09	0.18	0.13	0.10	0.13	0.22	0.17	0.18	1.00	
11. Environmental complexity	− 0.95	0.48	− 0.09	0.10	0.11	0.08	0.16	0.14	0.18	0.12	0.08	0.14	1.00
12. Environmental munificence	1.03	0.29	0.10	0.11	0.10	0.06	0.04	0.03	0.04	0.05	0.04	0.11	0.26
13. Patent depth	4.37	10.54	0.11	0.09	0.11	0.13	0.09	0.05	0.08	0.03	0.13	0.12	0.14
14. Patent breadth	3.72	13.27	0.09	0.07	0.16	0.11	0.12	0.10	0.14	0.17	0.16	0.19	0.22
15. CEO tenure	4.83	3.42	0.07	0.14	0.04	0.05	0.03	0.06	0.02	0.11	0.02	0.03	0.00
16. Sales growth	0.15	0.18	0.07	0.09	0.11	0.09	0.13	0.06	0.12	0.14	0.15	0.13	0.11
17. Employee growth	0.16	0.19	0.06	0.15	0.07	0.08	0.08	0.10	0.08	0.06	0.16	0.10	0.12
18. Operating profit growth	0.14	0.15	0.08	0.09	0.08	0.11	0.12	0.07	0.10	0.11	0.08	0.12	0.07
19. Highly standardized continuous flow manufacturing	0.20	—	0.07	0.03	0.05	0.05	0.03	0.02	0.07	0.06	0.06	0.03	0.06
20. High-volume mass production	0.22	—	0.02	0.06	0.05	0.02	0.06	0.07	0.06	0.05	0.05	0.06	0.05
21. Mid-volume assembly line	0.31	—	0.05	0.05	0.06	0.07	0.02	0.07	0.05	0.03	0.05	0.06	0.05
22. Mid-volume disconnected line and batch production	0.21	—	0.05	0.06	0.07	0.03	0.06	0.03	0.06	0.06	0.06	0.03	0.03
23. Specialized, low-volume job shops	0.27	—	0.06	0.06	0.05	0.03	0.02	0.03	0.03	0.02	0.07	0.04	0.04
24. Venture formalization	0.32	0.19	0.02	0.03	0.06	0.04	0.04	0.05	0.05	0.04	0.03	0.03	0.04

	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
1. Venture growth												
2. PPC												
3. Ambidexterity - level												
4. Ambidexterity- congruence												
5. Exploration												
6. Exploitation												
7. Absorptive capacity												
8. Size (#of employees)												

9. Age												
10. Environmental dynamism												
11. Environmental complexity												
12. Environmental munificence	1.00											
13. Patent depth	0.03	1.00										
14. Patent breadth	0.04	0.08	1.00									
15. CEO tenure	0.04	0.02	0.03	1.00								
16. Sales growth	0.12	0.07	0.17	0.07	1.00							
17. Employee growth	0.13	0.08	0.06	0.13	0.36	1.00						
18. Operating profit growth	0.11	0.07	0.19	0.09	0.41	0.30	1.00					
19. Highly standardized continuous flow manufacturing	0.04	0.06	0.06	0.05	0.05	0.02	0.05	1.00				
20. High-volume mass production	0.06	0.03	0.04	0.04	0.06	0.05	0.03	0.05	1.00			
21. Mid-volume assembly line	0.04	0.03	0.06	0.07	0.06	0.05	0.05	0.05	0.07	1.00		
22. Mid-volume disconnected line and batch production	0.03	0.06	0.03	0.05	0.05	0.05	0.03	0.03	0.06	0.05	1.00	
23. Specialized, low-volume job shops	0.03	0.05	0.07	0.05	0.04	0.03	0.05	0.05	0.03	0.06	0.06	1.00
24. Venture formalization	0.03	0.05	0.05	0.07	0.04	0.02	0.06	0.02	0.05	0.02	0.03	0.06

N = 215. All correlations above 0.07 are significant at 0.05 or below. All correlations above 0.13 are significant at 0.01 or below.

RESULTS

To test our hypotheses, we used moderated hierarchical regression. Based on recommendations by Aiken and West (1991), we mean centered the independent and moderating variables. The results are shown in Table 2. Hypothesis 1 predicted an inverted U-shaped relationship between PPC and firm performance. The results found support for this relationship ($\beta = -0.04$; $p < 0.01$).

Table 2. Hierarchical results

	Model 1	***Model 2***	***Model 3***
Direct effects			
Product portfolio complexity	0.23b	0.22b	0.21b
Product portfolio complexity^2 [H1]	− 0.05b	− 0.04b	− 0.04b
Ambidexterity-congruence	0.19a	0.18a	0.17a
Ambidexterity - level	0.15b	0.14b	0.13b
Absorptive capacity	0.29b	0.25a	0.25b
Linear moderating effects			
PPC × ambidexterity - level[3]		0.12b	0.11b
PPC × ambidexterity - congruence		0.10a	0.08a
PPC × absorptive capacity		0.13a	0.12a
Non-linear Moderating Effects			
PPC^2× ambidexterity - level			0.02a
PPC^2× absorptive capacity [H2]			0.04a
PPC^2× ambidexterity - congruence [H3]			0.03a
Controls			
Firm size	0.06	0.05	0.04

Firm age	0.05	0.04	0.03
Environmental dynamism	− 0.13a	− 0.13a	− 0.12a
Environmental complexity	− 0.16a	− 0.12a	− 0.12a
Environmental munificence	0.17a	0.13a	0.12a
Patent depth	0.07a	0.07a	0.07a
Patent breadth	0.07a	0.06a	0.06a
CEO tenure	0.05	0.04	0.03
Exploration	− 0.15b	− 0.15a	− 0.13a
Exploitation	0.12b	0.09a	0.08a
Highly standardized continuous flow manufacturing	0.04	0.03	0.04
High-volume mass production	0.06	0.03	0.05
Mid-volume assembly line	0.04	0.06	0.07
Mid-volume disconnected line and batch production	0.02	0.07	0.03
Specialized, low-volume job shops (reference)	—	—	—
Venture formalization	0.07a	0.06a	0.06a
Intercept	0.04a	0.03a	0.03a
F-stat	117.83 (20)	138.89 (23)	162.57 (26)
Adjusted-R^2	0.23	0.30	0.39
ΔF-stat		21.06 (3)***	23.62 (3)***
Adjusted-R^2		0.07	0.08
Sample size required for power = 0.95; $\alpha = 0.05$	172	168	152

Notes. N = 215

[a] $p < 0.05$;

[b] $p < 0.01$;

[c] $p < 0.001$.

To ensure the correct interpretation of the results, the significance of the inverted U-shaped relationship was assessed (Lind and Mehlum, 2010). First, we tested the joint significance of the direct and squared terms of PPC, following Sasabuchi's (1980) test for an inverted U-shaped relationship for PPC. Sasabuchi (1980) tests joint null hypotheses: (i) the effect of PPC on firm performance does not increase at low values of PPC, and (ii) the effect of PPC on firm performance does not decrease at high values of PPC. Then, we estimated the extreme point of effect of PPC and calculated confidence intervals based on Fieller's standard error and the Delta method (Lind and Mehlum, 2010). In addition, the confidence intervals for both the Fieller standard error and the Delta method indicate that the PPC values were within the limits of the data. As shown in Table 3, the inverted U-shaped relationship is significant.

Table 3. Test of an inversely U-shaped relationship between PPC and firm performance

	Firm performance
Test of joint significance of PPC variables [PPC and PPC-squared] (p-value)	0.01
Sasabuchi-test of inverse U-shape in PPC (p-value)[4]	0.01
Estimated extreme point	2.84
95% confidence interval—Fieller method	(2.25, 3.44)
95% confidence interval—Delta method	(2.29, 3.39)
Test of joint significance of control variables (p-value)	0.00
Test of joint significance of all variables in the model	0.00

Columns 2 and 3 in Table 2 offer a test for the remaining hypotheses with the addition of the moderating and nonlinear moderating variables. Hypothesis 2, which proposed the moderating effect of absorptive capacity on the inverted U-shaped effects of PPC, was supported ($\beta = 0.037$; $p < 0.05$). Hypothesis 3 similarly proposed that ambidexterity will enhance the effect of PPC on performance at higher levels of PPC. We also found support for this hypothesis ($\beta = 0.034$; $p < 0.05$). Drawing upon the recommendations of Cohen *et al.* (2003), we graphically depicted the nonlinear moderated relationships in Figure 1. Moderation effects are formally stated for absorptive capacity as:

$$Firm\ Performance = \beta_0 + \beta_1 PPC + \beta_2 PPC^2 + \beta_3 ACAP + \beta_4 PPC \times ACAP + \beta_5 ACAP^2 \times MF \ldots. \quad (5)$$

Rearranging Equation ((5))

$$Firm\ Performance = (\beta_1 + \beta_4 ACAP)PPC + (\beta_2 + \beta_5 ACAP)PPC^2 + (\beta_3 ACAP + \beta_0) \ldots. \quad (6)$$

As stated earlier, we centered the values of all variables in the moderation model. The three curves for high, average, and low values of absorptive capacity were plotted by substituting centered high (+1 standard deviation [s.d.]), average (mean), and low (−1 s.d.) values in Equation ((6)). As show in Figure 1(a), at low levels of absorptive capacity, the returns from PPC were almost flat, and the returns decreased rapidly as PPC increased. However, at higher levels of absorptive capacity, the returns from PPC were almost linear. Thus, at higher levels of absorptive capacity, the negative effects of PPC were mitigated. A similar interpretation is applicable to the ambidexterity moderator.

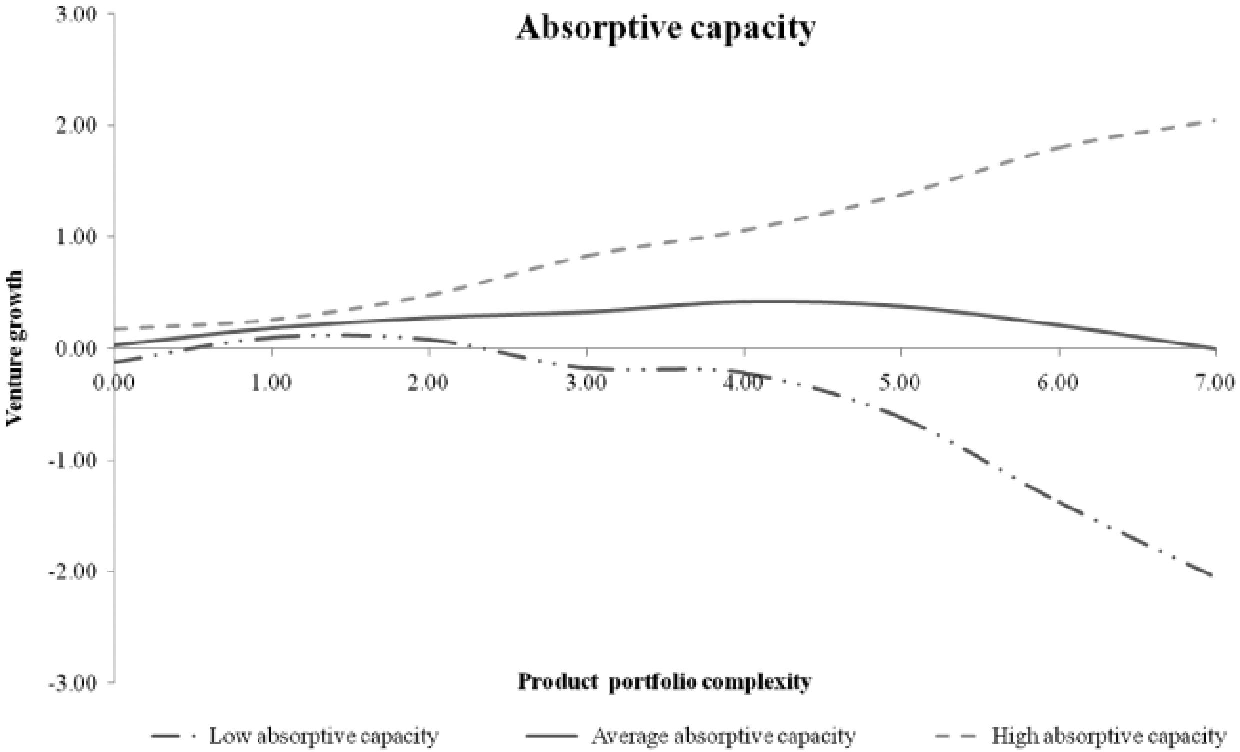

Figure 1(a): Moderation effects of absorptive capacity

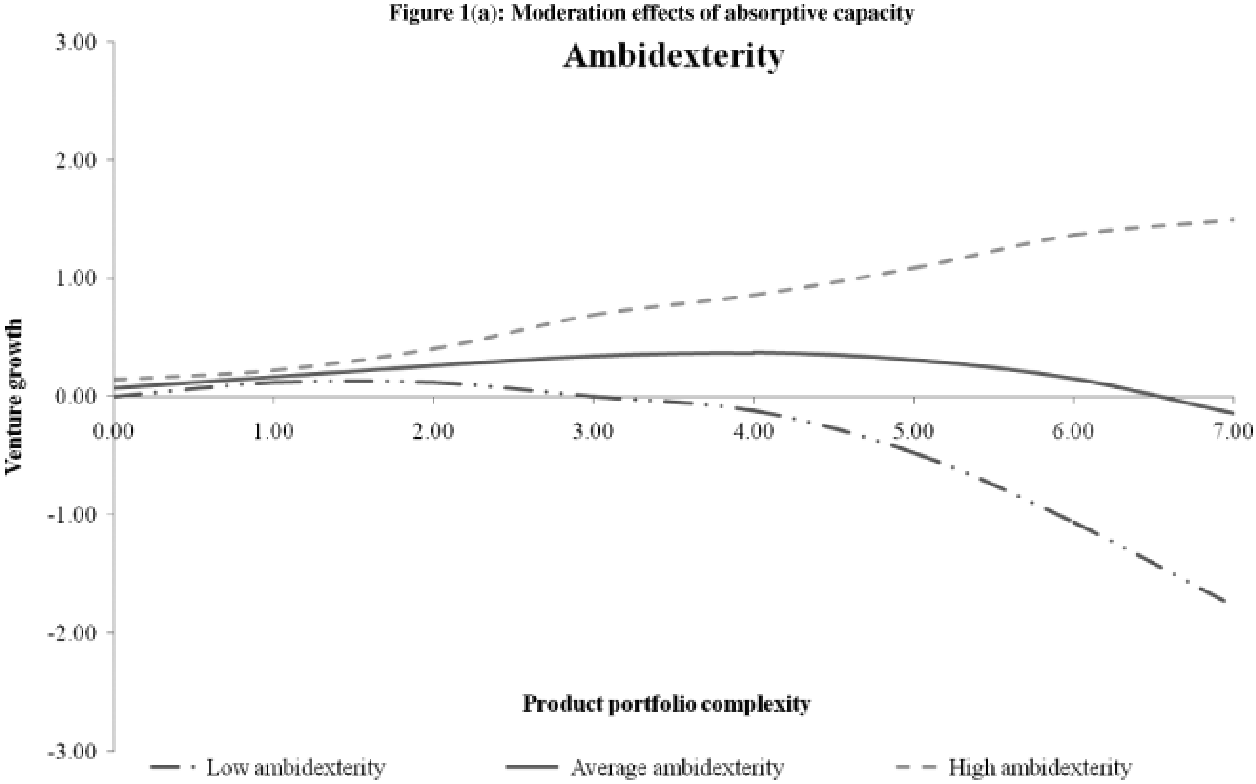

Figure 1(b): Moderation effects of ambidexterity

Post hoc analysis

We conducted several *post hoc* analyses to ensure that our findings are robust.5 First, as shown at the bottom of Table 2, our sample of 215 exceeded the minimum sample size of 152 for our most complex model (Cohen *et al.*, 2003). Drawing on Efron and Tibshirani (1997), we calculated power using a bootstrapping approach by drawing 1,000 replications. The power for the model of 0.87 was satisfactory (Cohen *et al.*, 2003). Second, we considered alternative measures of ambidexterity as proposed by Cao, Gedajlovic, and Zhang (2009) and others. The use of a combined measure (a plus b), a raw difference score (a minus b), or a multiplicative measure (a multiplied by b) did not change our results. Third, to ensure that our results were consistent under different conditions, we tested our models with self-reported performance on sales growth, operating profit growth, and return-on-assets growth to ensure consistency and facilitate alternative tests. While our inferences did not change, the effect sizes for self-reported performance data were higher than the effect sizes in the current model. Fourth, to test if there was heterogeneity in the effects due to different firm sizes, we split the sample into the following subgroupings based on employees: (a) < 50 (b) 50–100 (c) > 100. Although our inferences did not change, we observed that the effects were steeper for the smaller subgroup in each of the firms.

Fifth, although a 10-year cutoff has been used for ventures in prior empirical studies, it is possible that the results may be different based on venture age.6 We split the sample into ventures (a) younger than five years and (b) older than five years. Although the effect sizes for ventures older than five years were higher in magnitude than the effect sizes for ventures younger than five years, the statistical differences were not significant. A quantile regression assessing the effects of age on performance also proved insignificant ($\beta = 0.062$, $p = 0.593$).

Sixth, our measures for ambidexterity and absorptive capacity were single-respondent self-report measures. To assess the validity of the measures, we developed proxy measures from archival sources and correlated these measures with survey reports. To assess exploration and exploitation—the key components of ambidexterity—we developed a database of yearly product introductions in different product classes. If a venture introduced a product in a prior product class, we coded that as exploitation; otherwise, it was coded as exploration. Annual measures of exploration and exploitation were sums. In the next step, we used autoregressive-moving average to measure firms' persistence of exploration and exploitation in a time series. The correlation between self-report and archival measures were significant for exploration (Pearson $r = 0.59$, $p = 0.004$, two tailed) and exploitation (Pearson $r = 0.64$, $p = 0.001$, two tailed).

Similarly, absorptive capacity focuses on acquiring external knowledge and integrating it in internal knowledge stocks. Nooteboom (2000) and his subsequent work on cognitive distance suggests that the ability to absorb knowledge from distant sources enhances innovation capabilities. Similarly, work by March (1991) and Levinthal (1997) suggest that central to absorptive capacity is the ability to absorb knowledge from diverse sources. Ventures with increased technological distance can seek, identify, and absorb knowledge from diverse sources; therefore, technological distance can act as a proxy for absorptive capacity. To create a proxy measure for absorptive capacity, we used the patent portfolio of each young firm to develop a measure of technological distance from citations in patents. We started by identifying the three-digit technological class of each firm. In the next step, we listed all of the technological classes cited in the firm's patent portfolio. Based on the focal technological class of the firm, we calculated technological distance as:

$$Technological\ Distance = \frac{\sum_{c=0}^{C} w_c |tech\ class_c - focal\ class|}{P}$$

where *tech class*$_c$ is the technological class of cited patents, *C* represents all of the technological classes cited by the patents in the venture's portfolio, w_c is the citation weight of the technological class, and *P* is the total number of patents in the venture's portfolio. The Pearson correlation between technological distance and self-reported absorptive capacity was 0.481 ($p = 0.002$, two tailed). Overall, the self-report measures appeared reliable.

Finally, it is possible that high levels of ambidexterity or absorptive capacity could lead firms to increase PPC, which in turn affects firm performance. Utilizing the approach by Preacher, Rucker, and Hayes (2007), we did not find support for a partial mediation relationship (ambidexterity-congruence: $\beta = 0.137$; $p = 0.507$; absorptive capacity: $\beta = 0.082$; $p = 0.338$).

DISCUSSION AND IMPLICATIONS

PPC is becoming increasingly necessary for young technology firms to mitigate uncertainty and ensure competitiveness. Although PPC enhances sales growth opportunities, decreasing returns from increased complexity calls into question its true value. At higher levels of PPC, the costs of coordination and strain on management rise significantly. Our results confirmed an inverted U-shaped relationship between PPC and performance where at a given level of complexity, PPC begins to have decreasing returns on firm performance.

Although prior work acknowledges the presence of trade-offs, very limited, if any, larger-scale *empirical* evidence or *theoretical* exposition exists on how young firms can increase returns from PPC and mitigate the effects of reduced quality, increased costs, and lower profitability. In response to recent calls to better understand how firms can successfully manage higher levels of PPC (Closs *et al.*, 2008; Kim and Wilemon, 2009), we propose that organizational learning mechanisms play a vital role. Our results corroborate these arguments by demonstrating a positive moderating effect of both absorptive capacity and ambidexterity on the inverted U-shaped relationship between PPC and performance. This implies that through absorptive capacity, young firms can better integrate essential external knowledge into their management teams, thereby reducing the strain on their decision making and product development processes. Likewise, by creating a balance of exploitation and exploration through ambidexterity, young firms can reduce conflict and related coordination issues related to PPC because the organization's innovation goals are well understood.

As an extension of Closs and colleagues' (2008) model, we introduce learning, in addition to structure, as a systems-based response to managing complexity. Specifically, absorptive capacity helps control the flow of information by increased specialization within departments and more effective coordination among units. Such knowledge acquisition, assimilation, transfer, and exploitation mechanisms can also have an impact on how complex decisions are made across the organization. Ambidexterity sets organizational routines and processes to manage learning and innovation. Embedding ambidextrous routines in tasks and tools further facilitates the management of PPC.

An intermediate outcome from increased PPC is increased strategic flexibility. Through increased responsiveness to technological uncertainty and demand uncertainty, firms can overcome organizational inertia. Absorptive capacity as a dynamic capability helps reconfigure processes and routines to enable competitive advantage in turbulent environments (Eisenhardt and Martin, 2000). Ambidexterity could serve as an organizing principle for structuring and coordinating various resources and functional units to develop effective environmental responses (Zander and Kogut, 1995). Flexibility further reinforces organizational culture to engage in exploration-based innovation (Matthyssens, Pauwels, and Vandenbempt, 2005).

In a recent meta-analysis, Chen, Damanpour, and Reilly (2010) explained the central role of PPC in increasing the speed of innovation. In addition, Zhou and Wu (2010) suggested a more nuanced view of nonlinear returns from technological capability. Using R&D as a proxy for technological capability, King and Slotegraaf (2011) found nonlinear sales and profit growth from increased R&D spending. However, little guidance exists for how to manage the complexity of increased innovation. Our results indicate that organizational learning-based approaches could help enhance simultaneous exploration and exploitation activities. Firms could engage in increased ambidexterity through increased modularity in task tools and knowledge.

In terms of the ambidexterity literature, a central debate remains on the operationalization of ambidexterity. Traditionally, absolute difference scores or multiplicative scores were used (Raisch *et al.*, 2009). However, we provide a more robust operationalization, analogous to an absolute difference score while accounting for measurement errors and the measurement equivalence between exploration and exploitation.

In sum, our study supports the conclusion put forth by Raisch and Birkinshaw (2008) that the relationship between ambidexterity and firm performance is rather complex. Ambidexterity serves as a mechanism that helps young firms with complex product portfolios learn and, accordingly, contributes to their overall competitiveness. Likewise, although the role of absorptive capacity in increasing firm performance has been frequently highlighted in the literature (e.g., Lane *et al.*, 2001), our study suggests that greater attention should be paid to the contingent role of internal firm characteristics that help leverage absorptive capacity. Assuming technology capability is nonlinear (King and Slotegraaf, 2011), then an important question is how much is needed to benefit from external information?

Limitations and future research directions

The limitations of our study provide several directions for future research. First, our study focuses on young firms in high tech manufacturing industries. Given the criticality of new product development speed within these industries (Murtha, Lenway, and Hart, 2001), the importance of PPC may be magnified in the current study. It is indeed possible that PPC may be less important in lower tech industries, and subsequently, the impact of ambidexterity or absorptive capacity could differ. As younger firms rely more heavily on the external environment, they may also represent a more truncated distribution of PPC; thus, our findings may not be applicable to the highly complex product portfolios of larger firms (e.g., IBM).7 While small and high tech firms contribute significantly to economic growth (Agarwal, Audrestch, and Sarkar, 2007), future research would benefit tremendously by replicating the study with older firms, lower tech industries, and firms outside of the United States.

In the context of our empirical analysis, we acknowledge that our measures of ambidexterity and absorptive capacity are self-reported and are from a single source. Although the use of single-respondent, self-report measures is fairly common within these literature streams (refer to the recent special issue on ambidexterity by Raisch *et al.*, 2009 and a recent meta-analysis on absorptive capacity by Van Wijk, Jansen, and Lyles, 2008), the reliability of such measures remains a concern. Despite the drawbacks of using single-respondent, self-report data, the robustness analysis section suggests that this measure may not be a significant threat to the validity of our findings. Nonetheless, future studies would benefit from drawing on multiple sources when gathering ambidexterity and absorptive capacity measures.

Third, since our study is cross-sectional in nature, additional insight could be gained by examining the dynamics of PPC over time. Although the quantitative collection of longitudinal data may be quite difficult, qualitative approaches, such as those proposed by Langley (1999), to assess the development of PPC over time could be fruitful.

CONCLUSION

To address the needs of a complex and dynamic environment, young technology firms must increasingly adopt complex product portfolios. PPC help firms mitigate technical and demand uncertainty by rapidly introducing new products. However, increased complexity can lead to decreasing returns due to the coordination costs necessary to manage PPC. By absorbing external knowledge and adopting a balanced innovation perspective through ambidexterity, young firms can enhance their returns and mitigate costs from increased complexity.

APPENDIX - PARAMETER ESTIMATES AND ITEM RELIABILITIES

Scale description	**Items**	**Factor loading**	**se**	**PML**	**Jack-knife**	**Boot-strap$_{100}$**	**t-value**	**α**	**Raykov ρ**	**Ordinal rel.**
Performance	Sales growth (three years; D&B)	0.90	0.11	0.11	0.11	0.10	8.09	0.72	0.72	0.72
	Employee growth (three years; D&B)	0.74	0.14	0.14	0.13	0.13	5.10			
	Operating profit growth (three years; D&B)	0.78	0.15	0.15	0.15	0.14	5.21			
Exploration[8] (*1-strongly disagree to 5-strongly agree*)	Looks of novel technological idea by thinking 'outside the box'	0.90	0.12	0.12	0.12	0.12	7.28	0.87	0.88	0.88
	Bases its success on its ability to explore new technologies	0.86	0.23	0.23	0.22	0.22	3.78			
	Creates products or services that are innovative to the firm	0.76	0.23	0.22	0.22	0.22	3.39			
	Looks for creative ways to satisfy its customers' needs	0.86	0.13	0.13	0.12	0.12	6.80			
	Aggressively ventures into new market segments	0.76	0.25	0.25	0.25	0.25	3.01			
	Actively targets new customers groups	0.81	0.13	0.13	0.12	0.12	6.41			
Exploitation (*1-strongly disagree to5-strongly agree*)	Commits to improve quality and lower cost,	0.74	0.17	0.17	0.17	0.17	4.24	0.86	0.86	0.86
	Continuously improves the reliability of its products and services	0.76	0.13	0.13	0.12	0.12	5.95			
	Increases the levels of automation in its operations	0.69	0.17	0.17	0.17	0.16	4.13			
	Constantly surveys existing customers' satisfaction	0.77	0.26	0.26	0.26	0.26	2.92			
	Fine-tunes what it offers to keep its current customers satisfied	0.75	0.16	0.16	0.15	0.15	4.83			
	Penetrates more deeply into its existing customer base.	0.82	0.11	0.11	0.11	0.11	7.32			
Absorptive capacity 'Indicate the degree to which the following applies to your firm ….' [1—strongly disagree and 5—strongly agree]								0.87	0.88	0.90
Acquisition (AVE = 0.619)		0.91	0.25	0.25	0.24	0.24	3.66	0.85	0.87	0.89
	We have frequent interactions with other in the industry to acquire new knowledge related to product development.	0.79	0.17	0.17	0.17	0.16	4.66			
	Employees are engaged in cross-functional work	0.79	0.12	0.12	0.11	0.11	6.85			
	We collect information through informal means (e.g. lunch or social gatherings with customers and suppliers, trade partners and other stakeholders).	0.86	0.25	0.25	0.25	0.25	3.38			
	We are hardly in touch with other firms and stakeholders in the industry (reverse-coded)	0.82	0.25	0.25	0.25	0.25	3.22			

	We organize special meetings with customers, suppliers, or third parties to acquire new knowledge on process, product, logistics and distribution related innovation.	0.76	0.14	0.14	0.14	0.13	5.40			
	We operations regularly approach third parties outside the industry (such as professional organizations) to gather information.	0.76	0.12	0.12	0.12	0.12	6.14			
Assimilation (AVE = 0.582)		0.81	0.20	0.20	0.20	0.19	4.03	0.79	0.79	0.797
	We are slow to recognize shifts in the environment (e.g. competition, regulation and demography). (reverse-coded)	0.76	0.11	0.11	0.11	0.10	6.88			
	We are able to quickly identify new opportunities to meet our customer needs	0.74	0.16	0.16	0.15	0.15	4.63			
	We quickly analyze and interpret changing market demands.	0.89	0.18	0.18	0.18	0.18	4.87			
Transformation (AVE = 0.637)		0.84	0.25	0.24	0.24	0.24	3.42	0.81	0.81	0.809
	We regularly consider the consequences of changing market demands in terms of new products.	0.76	0.14	0.14	0.14	0.14	5.49			
	Employees record and store newly acquired knowledge for future reference.	0.82	0.22	0.21	0.21	0.21	3.83			
	We quickly recognize the usefulness of new external knowledge to existing knowledge.	0.76	0.12	0.11	0.11	0.11	6.59			
	Our employees hardly share practical experiences with each other. (reverse coded)	0.85	0.20	0.20	0.19	0.19	4.27			
	We laboriously grasp the opportunities from new external knowledge. (reverse-coded)	0.72	0.10	0.10	0.09	0.09	7.22			
	Departments periodically meet to discuss consequences of new product development and other process or organization innovation	0.82	0.14	0.14	0.14	0.14	5.80			
Exploitation (AVE = 0.604)		0.80	0.16	0.16	0.16	0.16	4.89	0.85	0.85	0.855
	It is clearly known how activities within and between departments should be performed.	0.85	0.24	0.24	0.23	0.23	3.59			
	We are less responsive to customer complaints (reverse coded)	0.79	0.21	0.20	0.20	0.20	3.83			
	We have a clear division of roles and responsibilities.	0.81	0.11	0.11	0.11	0.10	7.16			
	We constantly consider how to better exploit knowledge.	0.73	0.16	0.16	0.16	0.15	4.50			
	We have difficulty implementing new products and new processes (reverse-coded)	0.82	0.12	0.12	0.12	0.12	6.65			

Our employees speak a common language regarding our innovation practices	0.89	0.24	0.24	0.23	0.23	3.78

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