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The antecedents and consequences of product variety in new ventures: An empirical study

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ABSTRACT

Despite the known benefits of greater product variety for large firms, less is known about how new ventures pursue product variety. Liabilities of newness and smallness could possibly impede the ability of new ventures to develop the product design capabilities needed to increase product variety. Drawing on the design principles of product modularity, we posit that new ventures with modular product designs tend to have higher product variety. The benefits of product variety, however, are not monotonic, and at higher levels of product variety, increasing internal operational costs lead to an inverted-U type relationship between product variety and operational performance. We posit that process modularity, a systems-level capability, and manufacturing flexibility, an operations capability, enhance the benefits from product variety and mitigate the costs that arise from increasing product variety further. Based on a sample of 141 new ventures and using latent moderated structural model (LMS), we find support for the proposed model. The findings are robust against alternate model specifications. Academic and managerial implications from the findings are discussed.

1. Introduction

In the past two decades, the manufacturing base in the US has declined. The contribution of manufacturing to US GDP declined from 17.5% in 1986 to 12.1% in 2006.[2] Yet, small manufacturing firms remain a vibrant and growing part of the US economy. The Kauffman Foundation reported (Fairlie, 2011) that the number of manufacturing startups increased by 65% between 2000 and 2006. This number is particularly significant given that 70% of all US manufacturers have fewer than 20 employees. Furthermore, according to the US Census Bureau,[1] sales of small manufacturing firms grew by 20% between 2002 and 2006. While large manufacturers have focused on cost cutting, downsizing, and outsourcing, smaller manufacturers are relying increasingly on innovation and customization to revitalize the US manufacturing base.

Although the academic literature assumes that small firms lack economies of scale and scope to compete against larger firms high-growth manufacturing ventures in the Inc. 5000 list[3] increasingly provide greater product variety, with faster turnaround times, higher quality, and a smaller employee base. For example, with its 40 employees, Packrite provides a wide range of packaging and design solutions to consumer goods companies. Lumitec, a 15-employee firm with $3.4 million in sales, manufactures marine lights for recreational and law enforcement boats. Evolve Manufacturing, a manufacturer of electrochemical assemblies and systems for industries ranging from robotics and semiconductors to medical equipment, had 57 employees in 2012 and a revenue base of $41.4 million. Valley Rubber, with 105 employees, manufactures molded products used in industries ranging from marine and offshore drilling to railroads and bridges. All of these examples point to a common question: How do small and new ventures manage a diverse product portfolio with a small employee and resource base?

Given the increasing role that small and young manufacturing ventures play in the US economy, we explore the important issue of how new ventures manage increasing product variety. Product variety is defined as "the breadth of products that a firm offers at a given time" (Fisher et al., 1999: 297). Whereas larger and more established firms can manage product variety effectively, for new ventures, product variety can be a double-edged sword. On the one hand, product variety allows new ventures to increase product differentiation, efficiency, and product quality (Closs et al., 2008; Kekre and Srinivasan, 1990; Swaminathan and Tayur, 1998). On the other hand, lower product variety renders new ventures less competitive (Li and Atuahene-Gima, 2001). Also, new ventures face the liabilities of both newness and smallness (Aldrich and Fiol, 1994) and therefore have limited resources and capabilities to expand

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[1] Tel.: +1 765 285 3194.
[2] http://www.bea.gov/national/index.htm.
[3] http://www.inc.com/inc5000/list/2012/industry/manufacturing.

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their product offerings or manage increases in design, inventory, rework, and overhead costs. Ramdas (2003) indirectly confirmed by finding mixed effects of product variety on performance. It is likely that increased product variety could very quickly lead to declining returns in some ventures. For example, adding three products would be less burdensome for a large firm, whereas for a new venture to add the same level of three products could require significant investments and realignments that could lead to a significant decline in performance and even failure.

This begs the question of how small manufacturing firms can sustain growth and increasingly contribute to the US economy by offering greater product variety, when adding such variety could lower operational performance. To explain this paradox, we propose that *product modularity* can increase product variety in new ventures, whereas *process modularity* and manufacturing flexibility mitigates the inverted-U type relationship between product variety and operational performance. Operational performance refers to outcomes related to operational costs, product quality, and inventory management and delivery. Modularity in products or processes refer to “a continuum describing the degree to which . . . components can be separated and recombined, and it refers both to the tightness of coupling between components and the degree to which the ‘rules’ of the system architecture enable (or prohibit) the mixing and matching of components” (Schilling, 2000: 312). Product modularity enhances product variety by increasing possible reconfigurations to yield new product combinations. Product modularity helps increase internal variety to manage external variety.

According to Tu and colleagues (2004: 151) process modularity refers to “standardizing manufacturing process modules. . .so that they can be resequenced easily or new modules can be added quickly” to manufacture a variety of products. It includes process standardization, or standard subprocesses; process resequencing, or ability to reorder processes; and process postponement, or delayed differentiation (Feitzinger and Lee, 1997). Process standardization reduces internal variety of tasks, tools, and processes; process resequencing allows reconfiguration of manufacturing processes to reduce retooling, setup, and reordering costs; and process postponement allows moving manufacturing processes closest to their most pertinent point in the value chain. For example, Xtreme Power, a startup with 231 employees and $22.2 million in sales in 2011, designs, engineers, manufactures, and operates energy storage and power management systems for wind and solar power producers, transmission firms, and end users. Through highly standardized manufacturing processes, the company is able to use standard processes to make both wind and solar energy storage systems to lower costs. Because it caters to producers, transmitters, and end users, it leverages postponement by customizing the installation and operations of equipment and systems at various points along the value chain.

Manufacturing flexibility, an operations-level capability, helps new ventures cope with fluctuating customer demands through increased range-number and range-heterogeneity of manufacturing components (Nemetz and Fry, 1988). Whereas process modularity provides the broad design rules for manufacturing processes, manufacturing flexibility strategies deal with the detailed operational-level decisions that should comply with broad design rules. For example, range-mobility strategies reduce transition losses in manufacturing a wide variety of products, and a range-uniformity strategy ensures consistent product quality. Megan Summerville of SewSister is an apparel manufacturer that provides fast turnaround for small orders from designers and manufacturers. Her firm completes a vast range of apparel jobs on machines such as single- and double needle, serger, zigzag, and labeling devices that provide a fast turnaround of three to four weeks for quantities of 100 or fewer pieces of clothing. Manufacturing flexibility enhances the benefits of increasing product variety and mitigates costs that typically increase at higher levels of product variety. Overall, we propose that new ventures can increase product variety by using more modular product designs and can manage decreasing returns from product variety by using process modularity and manufacturing flexibility strategies.

2. Theoretical development and hypotheses

Product variety not only includes the number of unique product classes in a firm’s product portfolio but also the number of unique product varieties within each product class[4] (Fisher et al., 1999). Organization theory discusses the generalist–specialist tradeoff (Aldrich and Fiol, 1994). Generalist new ventures increase their chance of survival by meeting the needs of a variety of customers. However, generalist ventures lack the experience and resources of a large firm and therefore exacerbate risk of failure by offering broader product variety. Conversely, specialist new ventures face higher risks as they occupy narrow market niches and cannot adapt to changing customer demands. Product variety in new ventures is therefore a double-edged sword. By expanding product offerings, new ventures increase the horizontal scope or “the set commercialization efforts. Focusing on a smaller assortment of products could increase competitive response (Chatain and Zemsky, 2007: 550). The ability to provide product variety comparable to levels competitors could increase the legitimacy of the venture and ensure a steady inflow of resources to undertake future stability in the short run, but render ventures less competitive in the long run. Investors react positively to product launches by smaller firms (Lee and Chen, 2009). Greater product variety increases legitimacy among stakeholders, increases the flow of resources, and hedges the fledgling technical core of a venture against environment changes. Product variety spreads the loci of commercialization as a coping mechanism against changing market demands.

On the other hand, due to the liabilities of newness (younger firms face a higher risk of mortality) and smallness (smaller firms face a higher risk of mortality), small firms may not realize the full benefits of product variety and could realize lower performance and ultimately failure. The liability of newness refers to age dependence; that is, younger firms face a higher risk of mortality (Freeman et al., 1983). Younger ventures require scale and scope economies to mitigate costs under greater product variety (Shelton, 2005). Not only do limited resources hinder commercialization efforts, but limited organizational cognitive capabilities reduce comprehensive decision-making and the ability to seek and combine the knowledge needed to increase product variety. Internal learning curves are less able to cope with changing needs. Furthermore, gains from product variety could be realized to a lesser extent because of limited economies of scope and scale. A lower ability to recoup expenses for R&D, operations, and marketing due to lower scale efficiencies further constrains new product commercialization. Ventures must judiciously manage the tradeoffs between competitive gains from differentiating through greater product variety and increasing costs from higher product variety.

2.1. Product modularity and product variety

Both conceptual (Krishnan and Ulrich, 2001) and normative (e.g. Chen and Hausman, 2000) research highlights the

[4] Product variety, traditionally measured as the number of stock keeping units (SKUs), differs from product portfolio breadth, defined as the number of unique product classes in which a firm offers products.

Table 1
Architecture choices under product variety.

	Increasingly independent design	Increasingly unified design
	Decreasing modularity	**Increasing modularity**
Description	Components not shared among products	All products share one or more components
Manufacturing Costs	increasing internal variety of parts increase fixed production costs related to design and tooling required for unique parts; more parts increase production and scheduling complexity; scale economies are less possible due to heterogeneity in parts	As more components are shared internal variety of parts reduces fixed production costs reduced design and tooling costs for components; lower internal variety simplifies production and scheduling; due to fewer parts, scale economies are more possible.
Inventory	Due to more unique parts, greater raw material and work in process inventory	Due to shared parts lesser raw material and work in process inventory
Quality	Difficult to achieve; heterogeneous operational routines require greater monitoring and control and increased likelihood of rejects	Easier to achieve; with fewer components monitoring and control are easier, and leads to lower likelihood of rejects
Speed of delivery	Lower; due to longer assembly times and increase scheduling and production complexity	Higher; due to longer assembly times and increase scheduling and production complexity
Operational learning requirements	With increasing components separate manufacturing tasks, tools, and processes must be developed. This requires a venture to go down several learning curves	With fewer unique components fewer manufacturing tasks, tools, and processes are required. This requires a venture with liabilities of newness to go down fewer learning curves. There is additional operational learning required for developing tasks, tools, and processes for component interfaces.

importance of modular product architecture in increasing product variety. Architecture-based designs range from independent designs in which products do not share components to increasingly unified designs in which products share one or more components (Table 1). Independent designs reduce the cost of developing common interfaces among shared components. Because components are not shared, unified designs are more resilient, because failure of one product architecture does not affect another. Modular designs enhance the speed of innovation and reduce design and manufacturing costs (Pil and Cohen, 2006).

A broader range of combinations are necessary to identify commercially viable product configurations (Bordley, 2003). Advantages proffered by greater product modularity are particularly relevant in the new ventures context (Table 1). For new ventures, increasing modularity helps mitigate the liability of smallness effects by increasing product variety with smaller resource investments. Product modularity in new ventures lowers the learning and experimenting needed to develop new products and promotes the firm's ability to adapt to changing market demands. For young and small new ventures, learning-by-doing in independent yet related subsystems enables them to create combinations that increase product variety (Fujita, 2002). Subsequently, they realize design efficiencies despite their base of fewer resources and capabilities. By reducing architectural complexity through unified design, product modularity in new ventures facilitates rapid changes in individual subsystems with fewer resources. Shared components increase economies of scale, simplify production and scheduling processes, and lower inventory costs. Production and scheduling simplicity leads to fewer learning requirements because lower component variety helps mitigate the liabilities of newness. Furthermore, for a venture with a fledgling operational base, by increasing focus on fewer shared components, lower internal variety improves quality and reliability, which also enhance legitimacy among stakeholders. In sum, product modularity is necessary for small ventures to increase product variety under the constraints of liabilities of smallness and newness. Against this background, we propose our first hypothesis:

Hypothesis 1 *(:)*. Product modularity is positively related to product variety in new ventures.

2.2. *Non-linear effects of product variety and operational performance*

2.2.1. *Benefits of product variety*

Product variety uniquely positions a new venture to respond rapidly to new market opportunities, reduces product costs by increasing switching costs for customers (Martin et al., 1998), and enhances economies of scale and scope (Matutes and Regibeau, 1988). Internal coordination resulting from product variety increases the flow of knowledge across functional areas and accelerates knowledge recombination to build product portfolios that are robust against environmental changes (Henderson and Cockburn, 1994). Product variety promotes greater economies of scale and scope in developing, producing, marketing, and distributing products (Macher and Boerner, 2006) and increases customer responsiveness to ensure long-term survival (Rothaermel et al., 2006). For example, SewSister created a unique niche by providing fast turnarounds for small quantities of apparel orders.

2.2.2. *Costs of product variety*

Although product variety increases operational performance, after some point (especially for new ventures), costs associated with increasing product variety will increase at a faster rate than the benefits (Quelch and Kenny, 1994). In the mainstream literature examining product variety, researchers have found that too much product variety can be detrimental to performance. In examining the computer industry between 1981 and 1992, Bayus and Putsis (1999) noted that due to increasing costs under higher product variety, firms preferred narrower product lines, with product variety lowering market share, especially for startups. These effects could multiply for new ventures, whose tenuous resource base and limited operational capabilities could impede the firm's ability to offer high product variety. For example, Heartbreaking Dawns, a home-based gourmet spicy sauce venture that sells products in 14 countries decided to limit its product variety to 25 items to control brand dilution and manage operational costs.

Compared to large firms, which have significant assets and capabilities, new ventures risk spreading their limited resource base too thin by adding more products. Increasing product variety could also increase doubts of legitimacy and reliability among stakeholders, including customers, who could question a new venture's ability to meet a broader set of product demands effectively.

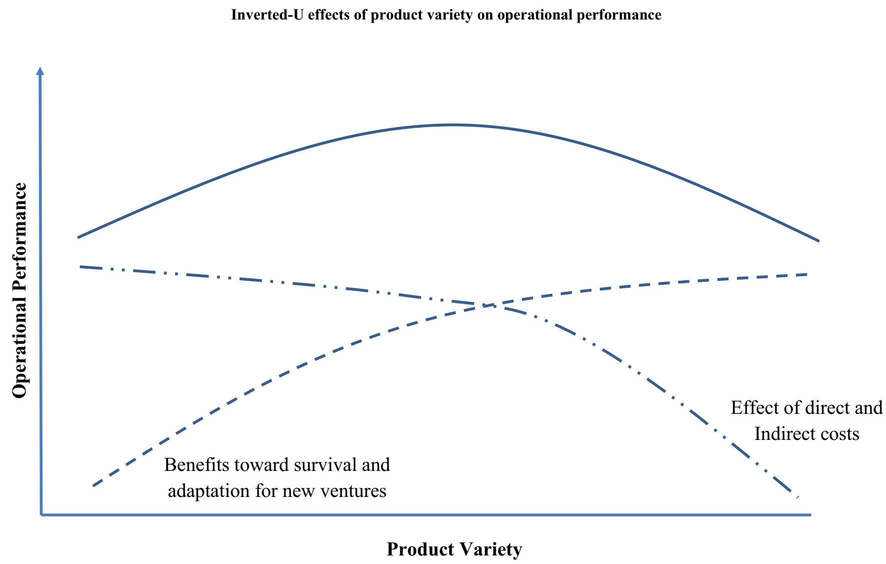

Fig. 1. Inverted-U effects of product variety on operational performance.

Furthermore, due to increasing fragmentation in the firm's product portfolio and a decline in economies of scale, higher product variety also increases design costs for new ventures that may experience resource constraints (Fisher et al., 1999; Lawrence and Spiller, 1983). An increase in product variety also requires complex assembly and supply processes (Hu et al., 2008), which could significantly increase costs for inventory and training costs (Van Ryzin and Mahajan, 1999), lower capacity slack (De Groote, 1994), and lead to longer assembly cycle times (Xia and Rajagopalan, 2009). Therefore, new ventures facing the liabilities of smallness and newness experience higher costs due to greater product variety, while accommodating changes to engineering designs, schedules, routings, material specifications, and bills of materials (Fisher and Ittner, 1999). Collectively, the inverted-U relationship generated by the benefits and costs of product variety is represented in Fig. 1.

To summarize, higher product variety helps new ventures meet market needs, increases legitimacy and reliability, and increases performance. However, at significantly higher levels, it taxes limited operational resources and increases costs. Formally, we propose our second hypothesis:

Hypothesis 2 *(:).* Product variety has an inverted-U type relationship with operational performance.

2.3. *Managing the benefits and costs of product variety*

We propose that new ventures need two capabilities, namely process modularity and manufacturing flexibility, to increase the benefits and reduce the costs that stem from increasing product variety. As discussed, process modularity constitutes process standardization, process resequencing, and process postponement. It is a systems-level capability in the sense that it sets the rules for process design. Related to process modularity, but at the operational level, is manufacturing flexibility, which translates the design rules for product and process at the operational level. In other words, it serves as a standard for executing the design rules. Manufacturing flexibility helps cope with product mix and design modification decisions. New ventures could manage their product variety by designing manufacturing processes into modules, resequencing, and postponement. In addition, new ventures can leverage commonality in machine use, labor content, material use, and material handling to yield higher levels of manufacturing flexibility.

2.3.1. *Process modularity and product variety*

Through standardizing processes, process modularity allows new ventures to reduce costs and learning requirements and enhance focus by fine-tuning operational processes. Process resequencing also allows for flexible manufacturing by simplifying line balancing and scheduling routines and lowering work in process inventory. This enables quick reconfigurations in manufacturing processes and sequences. Firms such as Specialty Blades (www.cadenceinc.com) manufacture a wide variety of blades (from surgical scalpels to industrial cutting blades) through process resequencing by allowing the manufacturing steps to be rearranged to enhance precision or strength of blades (Hise, 2007). Process postponement helps manage a venture's limited resources by delaying costly customization processes, lowering inventory costs, and increasing scale efficiency.

Modularizing operational systems lowers costs, improves learning, and increases productivity. Through process standardization, new ventures reduce the tight coupling among production processes, which also facilitates rapid realignment (Pine, 1993). Process modularization reduces learning complexities for new ventures as processing and storing products in semi-finished form helps buffer against demand uncertainty and allow faster turnarounds in order-cycle times. For new ventures, being faster than larger counterparts is a distinct competitive advantage. Triad semiconductor, for example, a venture with 28 employees and $5.1 million in sales in 2011, produces mixed-signal ASICs (application-specific integrated circuits) using standard integrated circuit manufacturing processes and then relies on process postponement to tailor ASICs for applications ranging from avionics and satellites to health monitoring systems. This results in lower costs and reduced inventory investments, which are beneficial to new ventures facing liabilities of smallness.

Other ventures provide examples of these concepts. FashionPlaytes uses its 500,000 customers to manage more than six million virtual designs via process modularity. Following a two-tier manufacturing approach, FashionPlaytes has standardized processes by developing basic designs, colors, and materials. Based on customer votes on these parameters, it postpones the process of adding ribbons, layers, and accessories. Process modularity allows FashionPlaytes to manage product variety with a turnaround time of two weeks and thus compete against large firms such as Levi-Strauss and Gap. Many wind power ventures rely on process standardization by making standard propeller-type (HAWT) mini-wind turbines and adding modules with Wind Amplified Rotor Platforms Systems to meet customer requirements. These examples suggest that modular processes promote realigning of operational processes to manufacture a broad range of products (Van Hoek and Weken, 1998).

To mitigate costs incurred from increasing product variety, process modularity has the benefit of lowering component manufacturing costs (Duray et al., 2000), lowering setup costs (De Groote, 1994), increasing delivery reliability (Lau Antonio et al., 2007), and enhancing quality (Salerno and Dias, 1999). All of these characteristics help mitigate spiraling costs under greater product variety. Using process standardization and process postponement and still increasing product variety, ChemStation, a provider of custom cleaning solutions, found that costs per customer fell by 25%. Despite its smaller resource base and a significant product variety, FashionPlaytes provides more value by providing customized clothing while keeping a low price of $20 per item, which is considerably lower than prices offered by comparable retailers such as Gap. Process modularity also facilitates process control and total quality management efforts (Lipták, 2006) by allowing quality inspections and control in smaller modules. Finally, efforts to standardize materials and process specifications lowers direct and indirect costs, as well as retooling, retraining, and reconfiguration costs for new ventures (Martin and Ishii, 2002). To summarize, process modularity provides component-level standardization that improves the benefits of product variety by facilitating rapid product launches and mitigating the associated operational costs of greater product variety. Based on this background, we propose:

Hypothesis 3 *(:).* Process modularity increases the benefits from product variety on operational performance and mitigates the increasing costs from product variety on operational performance.

2.3.2. Manufacturing flexibility and product variety

Flexibility enables firms to meet "increasing variety of customer expectations without excessive costs, time, organizational disruptions, or performance losses" (Zhang et al., 2003, page 173). Manufacturing flexibility helps new ventures manage product variety in several ways. Because most product variety in new ventures requires smaller batches and faster turnarounds, manufacturing flexibility allows firms to adapt their manufacturing rapidly to a certain number and volume of products. Demonstrating the ability to adapt to demand variability under greater product variety helps new ventures signal reliability to stakeholders (Morgan and Daniels, 2001). For example, in its small facility in Staunton, Virginia, Specialty Blades uses manufacturing flexibility to offer a broad product variety. Furthermore, manufacturing flexibility also helps new ventures that have a shorter operational history to more easily manage scheduling and routing flexibility of a complex array of products by compressing setup times and reducing the overall inventory in the system. Continuing from the earlier example of SewSister, manufacturing flexibility across five different types of machines helps this small firm simplify the flow of materials to turn out smaller batches of apparel at a faster rate. Greater operational adaptability to the volume and number of products is pivotal to developing rapid responses to varying customer needs.

In mitigating increasing costs from greater product variety, increased range mobility lowers assembly costs and improves material handling (Vokurka and O'Leary-Kelly, 2000). Furthermore, range-uniformity increases labor productivity through consistency in operational outcomes and lowers learning and training costs incurred in manufacturing diverse products. Through the range-number facet of manufacturing flexibility, both overproduction and inventory costs are reduced under increasing product variety. Range-mobility, meanwhile, enhances scheduling and routing flexibility because the system transitions to newer manufacturing processes to accommodate new designs. Finally, range-variety increases adaptability to customers' changing demand patterns. For example, S&S Cycle (sscycle.com), which builds high performance motorcycle engines and engine components, invested in rapid prototype casting machines to create plastic and wax parts. Specifically, using AutoCad design software and prototype machines lowered production times, improved labor productivity and lowered order turnaround time from a couple of weeks to 24 h. With a larger product variety, the cost of rejects and reworks of custom engine parts increases and labor productivity declines. Manufacturing flexibility, as facilitated by rapid prototyping machine test parts, makes adjustments and resubmits updated part designs faster, which could significantly lower manufacturing costs at high levels of product variety. With new technology that is capable of using prototypes to make a variety of parts, S&S compressed the time to make crankcases from two years to six months.

As these principles and new venture examples illustrate, manufacturing flexibility enhances operational benefits and mitigates costs at higher levels of product variety. Thus, we present our fourth hypothesis:

Hypothesis 4 *(:).* Manufacturing flexibility increases the benefits from product variety on operational performance and mitigates the increasing costs from product variety on operational performance.

3. Data description

3.1. Sample selection

The present study's theoretical framework focuses on how small firms manage product variety. Due to the liabilities of smallness and newness, we focus on young and small ventures that are ten years or younger and have fewer than 250 employees. Although there is no agreed upon definition regarding when a firm is considered "young," most studies have used varying age cutoffs of five, six, and ten years (Yang and Aldrich, 2012). Based on the recommendations of the Small Business Advocacy (SBA) group and National Federation of Independent Business (cf. Shane, 2008), we use a ten year cut-off, which is widely accepted among practitioners. Firms that are younger than ten years benefit from several state and federal programs that are designed to help small businesses (Link and Scott, 2012). Although firms in the US with fewer than 500 employees are considered small firms, we use a more conservative definition – fewer than 250 employees – which is also used by the European Union (Lukács, 2005). Overall, firms with fewer than 250 employees that are ten years or younger provides a sampling frame relevant to the theoretical framework. Furthermore, industry factors could affect product variety needs, and manufacturing and design technologies could affect the feasibility of product modularity and process modularity. For example, focusing on consumer electronics firms could positively bias findings, as products in these industries are more modular. In contrast, products in printed circuit boards having low modularity, could negatively bias the findings. Therefore, to draw generalizable inferences we draw on a wide variety of manufacturing industries.

3.2. Pilot study

We conducted a pilot survey among six academic researchers at a large Midwestern US university and eight CEOs of high-technology manufacturing firms in a large Midwestern city. We first sought feedback from academic researchers for the scales' face and content validity. Based on their feedback, we changed the order and wording of several survey items. Next, we conducted personal interviews with eight CEOs using the updated scales. Based on their feedback, we changed the wording of items that were difficult to interpret. We also developed a glossary of terms that helped the survey's final respondents provide the most valid, consistent, and reliable responses.

3.3. Survey

We drew data from the 2009 *CorpTech Directory* to identify 1,526 new ventures from 30 six-digit NAICS codes[5] with 10 to 250 employees located in the US states of Illinois, Indiana, Kentucky, Ohio, and Missouri. The *CorpTech Directory* is a reliable source of listings of technology firms and archival product data in the *Who Makes What?* section. The Directory provides a robust triangulation for survey responses on product variety.

A packet containing our survey, along with a cover letter and pre-paid business reply envelope, was sent to the CEO of each firm derived from the *CorpTech Directory*. The respondents were also informed that for every completed survey, US$20 would be donated to a charity of their choice. After mailing the survey packet and sending three follow-up reminder emails, we received responses from 219 CEOs, for a response rate of 14.35%. Low response rates (10–15%) are typical for surveys mailed to top executives and are comparable to other studies. (for a detailed discussion on survey response rates in organizational research, refer to Bartholomew and Smith, 2006; Baruch and Holtom, 2008) For the final dataset, we excluded 78 surveys that had incomplete data in the survey on product variety or SKUs based on the CEO's responses. This yielded a final sample size of 141 firms. We tested for non-response bias by comparing responses from early and late respondents and by comparing respondents and non-respondents on firm age, sales revenues, firm size (number of employees), NAICS codes, CEO age, and CEO gender. We found no significant differences based on any of these measures.

4. Variables

4.1. Operational performance

Our operational performance measure is based on Bowersox et al. (2000) and Inman et al. (2010). Operational performance metrics require measuring cost, quality, reliability, and profitability. Such measures, however, are not available in archival datasets; therefore, past studies have relied on self-reported operational performance measures (e.g. Qi et al., 2009). The scale items are listed in Table A1 in the Appendix A. The respondents were asked to evaluate the operational performance of their new ventures compared to their competitors based on the following scale: 1 = *much lower than competition*; 2 = *lower than competition*; 3 = *same as competition*; 4 = *higher than competition*; and 5 = *highest among competition*.

For the remaining measures discussed, we provide details on item loading and reliability (Table A1), confirmatory factor analysis (Table A2(a)), and discriminant validity (Table A2(b)) in the Appendix A.

4.2. Product variety

Aligning with past work on product variety, we used the total SKUs as a proxy for product variety (Alfaro and Corbett, 2003; Borle et al., 2005; Fisher and Ittner, 1999; Wan et al., 2012). The average SKUs were 39.43 (s.d. = 18.58), with a minimum of 13 SKUs and the maximum of 117 SKUs.

4.2.1. Triangulation of product variety

To verify the validity of a self-reported measure of SKUs, we correlated reported SKUs to the total number of products as reported in *CorpTech Directory's Who Makes What*? for new ventures. The *Who Makes What?* section reports unique products but not the number of products within each product class. Because SKUs relate to the total number of models or versions of a given product, the total number of SKUs is at least equal to if not greater than the number of products listed in *Who Makes What?* The correlation between self-reported SKU and number of products reported in *CorpTech* was 0.451 ($p < 0.001$, two-tailed).

4.3. Manufacturing flexibility

We used a second-order factor construct for manufacturing flexibility based on a comprehensive scale testing procedure proposed by Koste et al. (2004). The scale consists of five sub-dimensions relating to machines, labor, material handling, product mix, and modification flexibilities. Table A2(c) shows that a second-order factor of the five sub-dimensions is acceptable.

4.4. Product and process modularity

Product and process modularity are four- and five-item scales, respectively, based on Tu and colleagues (2004). As can be seen from the data in Table A1, the items for product modularity capture both the content domain of common and standardized design modules and adjustability and standardization of process configurations.

4.5. Controls

Larger new ventures are less likely to face liabilities of smallness and are therefore more likely to have resources to support greater product variety and invest in capabilities. To control for this aspect, we used *firm size* (the natural log of the number of employees) as reported in the *CorpTech Directory*. Likewise, older ventures are less likely to face liabilities of newness and are more likely to have established operational routines and processes (Nelson and Winter, 1982). To control for this feature, *firm age*, as measured in years since the organization was established and as reported in the *CorpTech Directory* was used.

Industry dynamics can impact operational performance significantly. Environmental dynamism, or variation in firm sales, could increase operational costs directly through increased inventory, obsolescence, and lower sales. Environmental complexity or heterogeneity among competitors increases process and product diversity at the industry level. Increased complexity leads to planning and forecasting challenges and reduces economies of scale. Finally, environmental munificence, or lower environmental hostility, indicates industry growth. Here, increased munificence could increase operational performance through higher demand. Controlling for these industry level dynamics

[5] Codes searched included the following: 334111 Electronic Computers; 334112 Computer Storage Devices; 334113 Computer Terminals; 334119 Other Computer Peripheral Equipment; 334210 Telephone Apparatus; 334220 Radio and TV Broadcasting and Wireless Communications Equipment; 334290 Other Communications Equipment; 335921 Fiber Optic Cables; 334310 Audio and Video Equipment; 334411 Electron Tubes; 334412 Bare Printed Circuit Boards; 334414 Electronic Capacitors; 334415 Electronic Resistors; 334416 Electronic Coils, Transformers, and other Inductors; 334417 Electronic Connectors; 334418 Printed Circuit Assembly; 334419 Other Electronic Components; 334413 Semiconductor and Related Devices; 333295 Semiconductor Machinery; 334511 Search, Detection, Navigation, Guidance, Aeronautical, and Nautical Systems and Instruments; 334512 Automatic Environmental Controls; 334513 Industrial Process Control Instruments; 334514 Totalizing Fluid Meter and Counting Devices; 334515 Electricity Measuring and Testing Equipment; 334516 Analytical Laboratory Instruments; 334519 Other Measuring and Controlling Instruments; 334510 Electromedical and Electrotherapeutic Apparatus; 334517 Irradiation Apparatus; 333314 Optical Instrument and Lens; 333315 Photographic and Photocopying Equipment.

Table 2
Mean, stansdard deviation, and correlation.

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Operational performance	2.85	0.89	1														
Product variety	39.43	18.58	0.23	1													
Product modularity	2.82	1.75	0.46	0.38	1												
Process modularity	2.06	1.01	0.35	0.26	0.19	1											
Manufacturing flexibility	3.09	0.86	0.22	0.22	0.23	0.26	1										
Size (ln[# of employees])	3.12	3.98	0.19	0.20	0.15	0.18	0.19	1									
Age	9.07	2.19	0.06	0.28	0.23	0.15	0.06	0.13	1								
Environmental dynamism	1.09	0.08	−0.15	0.23	0.19	0.25	0.18	0.17	0.18	1							
Environmental complexity	−0.95	0.52	−0.18	0.08	0.18	0.26	0.23	0.14	0.07	0.15	1						
Environmental munificence	1.03	0.29	0.17	0.08	0.27	0.22	0.09	0.09	0.05	0.12	0.26	1					
Patent depth	4.62	12.33	0.16	0.22	0.22	0.21	0.19	0.19	0.13	0.12	0.14	0.06	1				
Patent breadth	3.85	14.65	0.07	0.25	0.15	0.23	0.28	0.17	0.16	0.19	0.26	0.04	0.13	1			
CEO tenure	5.83	3.42	0.08	−0.05	0.23	0.25	0.08	0.11	0.02	0.03	0.13	0.18	0.02	0.04	1		
Production process (discrete)	0.38	–	0.11	0.07	0.15	0.18	0.13	0.12	0.13	0.04	0.06	0.15	0.08	0.19	0.15	1	
Production process (batch)	0.42	–	0.18	0.12	0.16	0.18	0.17	0.12	0.11	0.06	0.08	0.19	0.16	0.12	0.14	0.16	1
Production process (continuous)	0.20	–	0.07	0.09	0.08	0.06	0.22	0.09	0.12	0.06	0.06	0.08	0.12	0.16	0.19	0.12	0.14

Notes: All correlations above |0.09| are significant at 0.05 or below (two-tailed), all correlations above |0.14| are significant at 0.01 or below (two-tailed).

is essential to eliminate rival explanations of industry related effects on operational performance. We control for three industry level measures—*environmental dynamism*, *environmental complexity*, and *environmental munificence*. Measures of munificence and dynamism are based on the work of Dess and Beard (1984) and Heeley et al. (2006). Munificence is measured by averaging the anti-log of regression coefficients of a given industry's natural log of net sales and natural log of operating income over a 5-year period (2005–2009). Dynamism is the average of the anti-log of standard errors of the regression slopes from regression equations used in calculating industry munificence. Net sales and operating income figures were drawn from the COMPUSTAT database. Environmental complexity is derived by regressing the market shares of all firms in an industry in 2009 on the firms' market shares in 2005. Complexity indicates a trend either toward or away from large-firm market dominance. To ease the interpretation, and in line with Heeley et al. (2006), we multiply the coefficient by −1, such that a higher number indicates greater complexity. Data on market share were drawn from the COMPUSTAT database.

Because new ventures with greater product variety are more likely to have a broader knowledge base, we control for *patent depth* and *patent breadth*. We compiled patent information from the United States Patent and Trademark Office database. Patent depth is the average number of patents in each three-digit technological class, whereas patent breadth is the total number of technological classes for which a new venture filed for patents. In new ventures, longer-tenured CEOs are assumed to be more familiar with and involved in understanding, developing, and influencing functional capabilities such as operations. *CEO tenure* is the number of years that the CEO is listed in the *CorpTech Directory*. Finally, because operational processes could impose varying operational challenges, we control for three types of production processes—*discrete, batch, and continuous* (Avittathur and Swamidass, 2007).

As shown in the Appendix A, the proposed measures show adequate convergent and discriminant validity. Additional details on measurement validity and common method bias are discussed in Appendix B.

5. Results

5.1. Structural Equation Modeling (SEM) and other results

Table 2 lists the correlations among the variables. We observe low- to moderate levels of correlations. Based on prior approaches, we used the latent moderated structure (LMS) approach to model interaction and non-linear relationships (Klein and Muthén, 2007). Previous approaches on modeling interactions suffer from biases and unstable estimates, which are mitigated by LMS. While a detailed discussion on the advantages of LMS is beyond the scope of this work, we refer interested readers to Marsh et al. (2006).

The proposed model (Table A3) shows adequate fit ($\chi^2 = 1385.64$; df = 994; CFI = 0.934; TLI = 0.926; RMSEA = 0.039; RMSR = 0.022) and is significantly different from the null model ($\Delta\chi^2 = 418.662$; Δdf = 19; $p < 0.001$). It is not significantly different, however, from a saturated model ($\Delta\chi^2 = 51.076$; Δdf = 48). Because the proposed model is more parsimonious than a saturated model, we proceeded with the proposed model and tested whether alternate models provided a better fit. Tests of alternate models and vanishing tetrads test showed that the proposed model provides a better fit (Appendix C).

5.2. Main analysis

Fig. 2 shows the estimates of the main analysis. Hypothesis 1 proposed a positive relationship between product modularity and product variety and was supported ($\beta = 0.272$; $p < 0.01$). Hypothesis 2 proposed that product variety had a non-linear relationship with operational performance; this proposition was also supported ($\beta = -0.071$; $p < 0.05$).

Drawing on recent works by Blanchflower (2007) and Lind and Mehlum (2010), we tested the extent to which the inverted-U relationship is valid in the context of our data. First, we tested the joint significance of direct and squared terms of product variety on operational performance. Second, using the Sasabuchi (1980) test, we examined the validity for an inverted-U shape relationship of product variety on firm performance. The Sasabuchi (1980) test verified a joint null hypothesis: (1) operational performance decreased at low values of product variety, and (2) operational performance increased at high values of product variety. Third, we estimated the extreme point of the inverted-U effect of product variety and calculated confidence intervals based on Fieller's standard error and delta method (Lind and Mehlum, 2010). The inflection point (or the extreme point) must be within the data range. Table 3 shows that the direct and squared terms of product variety on operational performance were jointly significant. The Sasabuchi test was rejected, and the extreme point (and the confidence interval) was within two standard deviations of the product variety measure.

Hypothesis 3 proposed and found a moderation effect of process modularity on the relationship between product variety and operational performance ($\beta = 0.396$; $p < 0.001$). As proposed in Hypothesis 4, manufacturing flexibility positively moderates the inverted-U relationship ($\beta = 0.135$; $p < 0.05$). Drawing on

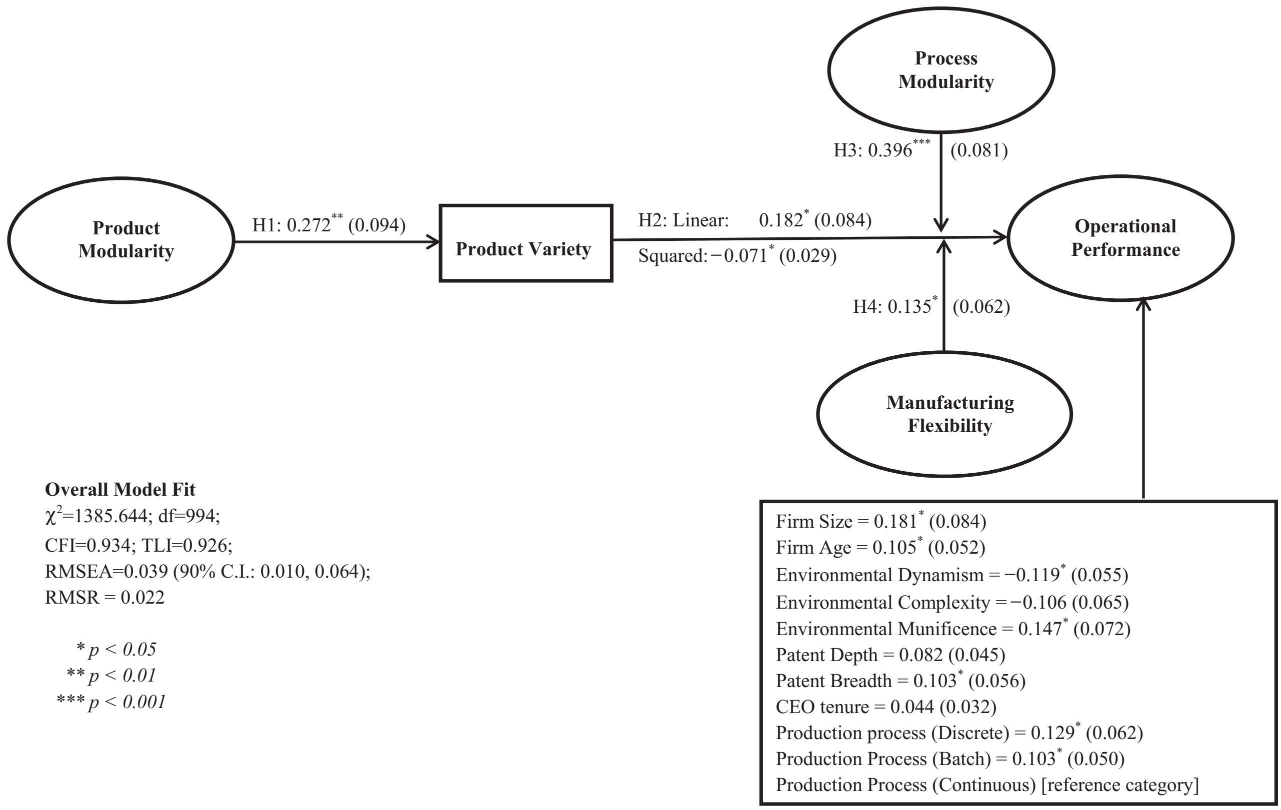

Fig. 2. Latent Moderated Structure (LMS) Estimates.

recommendations from Cohen et al. (2003), we show non-linear moderation effects using the following equation of moderation effects of process modularity (PV = Product variety; ProcessMod = Process Modularity):

$$\text{Operational Performance} = \beta_0 + \beta_1\text{PV} + \beta_2\text{PV}^2 + \beta_3\text{ProcessMod} + \beta_4\text{PV} \times \text{ProcessMod} + \beta_5\text{PV}^2 \times \text{ProcessMod} \quad (1)$$

and rearranging Eq. (1), we arrive at

$$\text{Operational Performance} = (\beta_1 + \beta_4\text{ProcessMod}) \times \text{PV} + (\beta_2 + \beta_5\text{ProcessMod})\text{PV}^2 + (\beta_3\text{ProcessMod} + \beta_0) \quad (2)$$

Based on Eq. (2), low (−1 s.d.), average (mean), and high (+1 s.d.) values of process modularity were plotted in Fig. 3a. Table 3 shows that the null hypothesis of the Sasabuchi test for both low- and high levels of process modularity were rejected, and the delta- and Fieller-based confidence intervals showed that the extreme point of product variety at low and high levels of process modularity were within the range of the data. Similarly, inverted-U effects for manufacturing flexibility were plotted in Fig. 3b, and inverted-U plots at high- and low values of manufacturing flexibility were within the range of product variety (Table 3).

5.3. Post-hoc analyses

First, statistical power using a bootstrapping approach by drawing 1,000 replications was 0.82 at $p = 0.01$ (Efron and Tibshirani, 1997). Second, to test for heterogeneity in the effects due to different firm sizes, we divided the sample into three groups:

Table 3
Test of an inverse U-shaped relationship between product variety and performance.

	Mean product variety	Low process modularity	High process modularity	Low manufacturing flexibility	High manufacturing flexibility
Test of joint significance of Product Variety [Product Variety and Product-variety squared] (p-value)	0.023	0.024	0.030	0.028	0.037
Sasabuchi-test of inverse U-shape in product variety (p-value)[a]	0.030	0.027	0.029	0.032	0.045
Estimated extreme point	42.924	31.252	60.005	34.152	68.756
95% confidence interval (Fieller method)					
Low	21.820	7.326	37.185	9.280	48.574
High	64.028	55.179	82.825	59.024	88.939
95% confidence interval (delta method)					
Low	17.584	3.577	40.885	11.822	51.826
High	68.264	58.927	79.125	56.482	85.686

[a] Sasabuchi (1980) proposed a test of composite null hypothesis that the relationship is increasing at low values of the EO interval and/or is decreasing at high values.

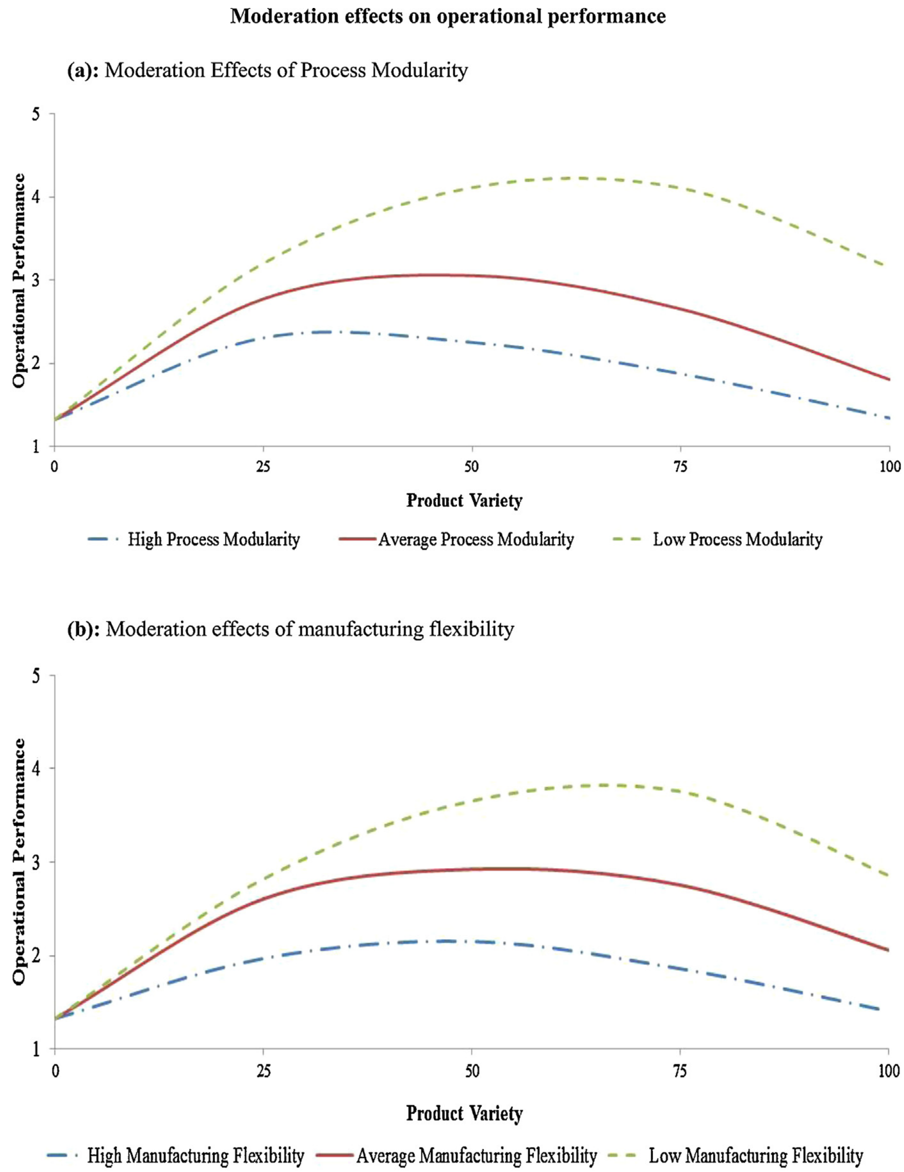

Fig. 3. Moderation effects on operational performance. (a) Moderation effects of process modularity. (b) Moderation effects of manufacturing flexibility.

(1) ≤50 employees, (2) between 51 and 100 employees, and (3) more than 100 employees. Although our inferences did not change, we observed that the effect sizes were higher for smaller firms. Third, we conducted additional robustness tests based on industry membership.[6] We used three SIC codes — 333, 334, and 335 — to classified firms into categories. The estimates were consistent in direction and significance. Furthermore, we classified firms based on production processes — discrete, batch, and continuous. The estimates were also consistent in direction and significance. Finally, because prior work called for using growth as a measure of new venture performance (Gilbert et al., 2006), we used 3-year sales growth as an alternate outcome measure from *CorpTech*. The findings were consistent in direction, magnitude, and significance (H1: $\beta = 0.143$, $p < 0.05$; H2: $\beta = -0.056$, $p < 0.05$; H3: $\beta = 0$ .228, $p < 0.01$; H4: $\beta = 0.107$, $p < 0.05$).

[6] We thank an anonymous reviewer for this suggestion.

6. Discussion and implications

Both the operations management and entrepreneurship literatures have focused to a limited extent on the operational capabilities that are relevant to new ventures and how new ventures can manage strategic imperatives by leveraging operational strengths. The growing importance of understanding operations management issues in new ventures is evident from the introductory articles in two recent special issues of the *Journal of Operations Management* (Kickul et al., 2011) and *Production and Operations Management* (Joglekar and Lévesque, 2013). Drawing on the established theoretical base of liabilities of newness and smallness and by using real-world business examples of small ventures, we explored how ventures could derive greater returns from product variety. One of the key starting points for new ventures is to identify, develop, and commercialize a business opportunity. To hedge against changes in customer demand, ventures must decide on the loci of their product offerings. Gains from product variety that could enhance initial performance, however, higher product variety could also lead to lower performance. The paradox of managing increasing product variety is pivotal to new ventures. On the one hand, greater product variety helps new ventures meet market demands, increase legitimacy and reliability, and hedge against the risk of putting all products "in one basket." On the other hand, relative to their larger counterparts, smaller ventures face significant challenges in managing product variety. Excessive product variety could increase operational costs, lower legitimacy and reliability, and potentially spread tenuous resource and capabilities bases too thin. We proposed how ventures can manage this important duality. To our knowledge, this is one of the earliest studies that contrasts past research work that has focused on how product variety is managed in large and established firms and exclusively addresses unique challenges in managing product variety in new ventures.

Also, drawing on recent calls to use contingency theory in operations management (Sousa and Voss, 2008), we explore the duality among new ventures in developing and managing product variety by examining the contingency effects of process modularity and manufacturing flexibility. With limited operational resources and capabilities, new ventures could focus on a narrow configuration of products to manage learning and control costs. However, this lower product variety reduces competitiveness and increases the likelihood of failure. Increasing the horizontal scope of the firm through greater product variety is necessary to meet latent or changing customer demands. With their limited resources and capabilities, new ventures must focus selectively on realizing benefits and mitigating costs from product variety.

By creating a "sandbox" of components that can be used to develop products, modularity seems relevant to increasing product variety in resource-constrained firms. More importantly, managing declining returns to operational performance is even more critical for ventures to maintain stable operations and recoup investments to reinvest in the next innovation cycles. Compared to larger firms who have resource buffers, gains from product variety are not simply a matter of competitive advantage but a matter of survival. The role of process modularity and manufacturing modularity is pivotal to increasing benefits and lowering the costs of product variety. Although the relevance of product modularity has been acknowledged conceptually (e.g. Schilling, 2000) and mathematically modeled (Sosa et al., 2004), its empirical effects on product variety remains unexplored. This is one of the few studies to explore this relationship empirically.

Indeed, we found support for inverted-U effects from product variety to operational performance in new ventures. Support for the mixed effects of product variety on performance is in line with Ramdas (2003). Furthermore, prior studies on the effects of product modularity and product variety have been conceptual, analytical, or qualitative (Ramdas, 2003). The present study is one of the very few empirical studies that attempts to unravel unexplored relationships involving product variety by exploring its antecedents and consequences of declining returns. Although the liabilities of newness and smallness could "range restrict" efforts toward increasing product variety, ventures in the data do leverage product variety to enhance performance. We also allowed for alternative configurations of relationships and found that our originally hypothesized model was the most robust and theoretically logical. Notably, removing the non-linear effects significantly weakened our originally hypothesized model (Model 5, Table C1, Appendix C).

We also proposed broader effects of modularity beyond the task, sequencing, part, and component levels, which prior literature has suggested (Salvador et al., 2002). Related research on modularity has focused on the role modularity plays in promoting innovation at the product level (e.g. Sanchez and Mahoney, 2002) or at the project level (Brusoni and Prencipe, 2001). Furthermore, research on product architectures has focused on its direct effects on firm performance (Fujita, 2002; Sosa et al., 2004). However, intervening mechanisms — the colloquial black box — that explain the effects of product architectures on product variety are seldom explored. We explore this black box by explaining how new ventures manage increasing product variety. More important, whereas modularity in manufacturing practices (Closs et al., 2008) have been explored increasingly in operations management research (Salvador et al., 2002), we also focus on an often neglected component — process modularity specifically for new ventures.

In contrast to prior studies (Fisher et al., 1999), we argue that the inverted-U effect of product variety on operational performance can be managed via high manufacturing flexibility. Manufacturing flexibility mitigates increasing costs and enhances the benefits of increasing product variety. To this extent, the present research makes a novel contribution to the literature, specifically within the context of new ventures. Notably, a comprehensive examination of manufacturing flexibility as mentioned in the seminal works of Koste et al. (2004) and Gerwin (1993) was undertaken in this study.

6.1. Practical implications

Entrepreneurs must make judicious choice on whether to increase product variety. Due to lack of resources and learning capabilities if entrepreneurs are unable to fully comprehend customer needs or predict future changes in demand by offering higher product variety they could invite their firm's demise. Lacking system-level and operational capabilities, entrepreneurs could focus on limiting excessive product variety and focus on niches unless strong modularity architectures and manufacturing flexibility routines are embedded in operations. The present study also suggests developing specific design rules for product modularity, such as sharing common modules, features, and reassembly to create new product options. Such considerations must be taken in account when entrepreneurs seek and develop opportunities. Some specific suggestions include building modular designs that are simple but yet allow adding product features around the base model. New ventures should also consider investing in reconfiguration kits by which customers design the options they need based on a common set of basic features. This is similar to what large toy manufacturers such as LEGO, Mattel, and Hasbro have done. Similar examples are seen in the furniture industry as demonstrated by companies such as IKEA, Steelcase, and Herman Miller. New ventures might do well by mimicking this strategy. One possible tool to achieve this is design for disassembly (DDA), which is enhanced through technologies such as rapid prototyping. An example cited earlier was S&S, which has invested in this tool. Closely related to the design rules for product modularity is design rules for process modularity. In setting up their operations, we recommend that entrepreneurs, focus on process modularity design rules that include: (1) processes that have adjustable modules; (2) processes that are easy to upgrade (or augment); (3) processes that can be modified to accommodate changing product needs; (4) processes that can be decomposed into standard modules and customized modules; and (5) processes that can be rearranged and resequenced. In particular, sub-strategies 4 and 5 can be used as effective postponement strategies as illustrated in the new venture business examples presented previously.

The present study suggests that new ventures should check the validity (or conformance) of design rules as they make detailed operational decisions of manufacturing flexibility regarding (1) machine flexibility, (2) labor flexibility, (3) material handling flexibility, (4) mix or product line flexibility, and (5) modifications or customer-needs flexibility. Naturally, one would expect a temporal order to investing in these sub-flexibilities. Although this was beyond the scope of this study, we expect that a dominant order (perhaps driven by customers) will guide the gradual buildup of capabilities in the sub-areas of manufacturing flexibility. To summarize, new ventures can benefit by using these design rules as an audit tool to gauge how successful their product modularity capability and process modularity are at any future point in time.

6.2. Limitations and future research

Inferences from the current study and its limitations provide directions for future research. First, the measures of product and process modularity are self-reported. While most prior studies have used this survey-based measure, future studies could take a fine-grained approach by focusing on product and process architectures. Second, we focused on the high-technology manufacturing industry sector. It is likely that the results may not generalize to low-tech or medium-tech industries. Third, as new ventures develop their product portfolios for the first time, we focus on one dimension of product variety–diversity of products offered. This notion could be important to older and more established firms. Future research focusing on this dimension could explain how firms renew their product portfolios and whether proposing operational capabilities is relevant. Fourth, and as Hoetker (2006) proposed, product modularity may not directly translate into modular structures.[7] It is likely that the presence of product modularity may not translate directly into process modularity or modular structure in operational processes. Although Model 4 in Table B1 relating to alternate model tests does not provide acceptable fit, future studies could focus understanding the process of designing and managing operational systems that draw on modular products. Finally, the present study does not specifically examine modularity related supply chain issues. For example, how do the suppliers' product and process strategies align with the firms' product and process strategies? As studies on supply chain management indicate, most firms, in particular new ventures, need to establish their purpose and value-added status within complex networks that embody today's supply chains (Avittathur and Swamidass, 2007).

7. Conclusion

To remain viable, new ventures facing the liabilities of newness and smallness must balance the benefits and costs of product variety. In particular, product modularity is central to increasing product variety in new ventures. By integrating two decades' worth of past literature that reported mixed findings regarding the effects of product variety on operational performance, we use an operational lens to explain why some new ventures realize higher gains from product variety. Our results point out that process modularity and manufacturing flexibility are vital to enhancing benefits and mitigating costs from increased product variety.

Acknowledgements

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Appendix A.

Tables A1 and A2.

[7] We thank an anonymous reviewer for this suggestion.

Appendix B. Measurement validity and common method variance

To ensure that multicollinearity was not a concern, we calculated the variance inflation factors (VIF). The rule of thumb is that VIF > 4.0 indicates a multicollinearity problem. All VIFs were less than 3.471, and the condition index did not exceed 7.632, which further suggested that multicollinearity is not a threat to the validity of our results (O'brien, 2007). The fit indices were as follows for the overall measurement model: $\chi^2 = 1385.644$; df = 994; CFI = 0.934; TLI = 0.926; Root Mean Square Error of Approximation (RMSEA) = 0.039; SRMR = 0.022. The fit indices met or exceeded the minimum threshold value of 0.90 as suggested by Hu and Bentler (1998). Therefore, based on these results, the measures are acceptable in terms of convergent and discriminant validity and overall fit.

To assess the threat of common method variance, we followed the guidelines by Podsakoff et al. (2003). First, we conducted Harman's factor analysis by entering all the variables used in the analysis for a factor analysis. Eight factors with eigenvalues > 1.0 were extracted, accounting for 83.07% of the variance. The first factor accounted for 22.46% of the variance. Because more than one factor was identified and individual factors accounted for the majority of the variance explained, common method bias was not a major issue. Second, we estimated a hypothesized model with an additional method factor to control for any influence that common method variance could impose on the estimated relationships (Podsakoff et al., 2003). The method factor explained 2.64% of the variance, with the measures in the proposed model explaining 65.57% of the variance. Although the possibility of common method bias cannot be ruled out fully, the tests indicate that it may not have confounded the relationships between our independent and dependent variables.

Appendix C. Tests for alternate models

We test for model fit of the proposed model against alternate models and conduct a vanishing tetrads test. Alternate models and model fit statistic are shown in Table B1. In Model 2, based on the "strategy drives structure" paradigm, it is likely that increasing product variety could drive initiatives to increase product and process modularity (Hayes and Wheelwright, 1979). Higher manufacturing flexibility could further facilitate realigning the operational resources needed to accommodate product variety through increased product and process modularity. However, Model 2 significantly differed from Model 1 ($\Delta\chi^2 = 18.69$; Δdf = 1; $p < 0.001$); in fact, it provided a much worse model fit (CFI = 0.871; TLI = 0.864; RMSEA = 0.142; RMSR = 0.113). We therefore chose a better fitting Model 1 (the proposed model).

Table C1.

Next, in Model 3, organizational structure literature in entrepreneurship (Kazanjian, 1988) proposed that modular design could drive strategic choices in ventures. Because ventures are developed by input from multiple stakeholders and extensive planning, ex-ante design choices could facilitate the level of product variety. Therefore, to assess if "structure drives strategy," rather than using process modularity as a moderator (as in Model 1), we tested whether process modularity, in addition to product modularity, serves as an antecedent to product variety. The logic here is that higher levels of process modularity could also drive firms to seek greater product variety. Model 3 did not provide a better fit ($\Delta\chi^2 = 8.620$; Δdf = 0; $p < 0.001$; CFI = 0.853; TLI = 0.846; RMSEA = 0.162; RMSR = 0.185).

In Model 4, we extend Model 1 by adding a link from product modularity to process modularity. The rationale is that

Table A1
Parameter estimates and item reliabilities.

Scale description	Items	Factor Loading	α	
Operational Performance "Please evaluate your operational performance relative to your competitors (1 = *much lower than competition* to 5 = *highest among competition*)			0.784	
	Inventory availability relative to our competitors.	.880***		
	Maintaining available inventory compared to our major competitors.	.876***		
	Product quality.	.804***		
	Order-to-delivery cycle time.	.904***		
	Operating profit.	.881***		
	Inventory turnover.	.880***		
	Operating profit growth.	.876***		
Process Modularity[a]			0.857	
	Our production process is designed as adjustable modules.	.840***		
	Our production process can be adjusted by adding new process modules.	.893***		
	Production process modules can be adjusted for changing production needs.	.816***		
	Our production process can be broken down into *standard sub-processes* that produce standard base units and *customization sub-processes* that further customize the base units.	.709***		
	Production process modules can be rearranged so that customization sub-processes occur last.	.722***		
Product Modularity[b]				
	Our products use modularized design.	.827***		
	Our products share common modules.	.849***		
	Our product features are designed around a standard base unit.	.796***		
	Product modules can be reassembled into different forms.	.906***		
	Product feature modules can be added to a standard base unit.	.910***		
Manufacturing Flexibility[c]			.826	
Machine Flexibility		.821***	.851	
	Range Number - The number of different operations that a typical machine can perform is high.	.828***		
	Range Heterogeneity - Machines can perform operations which differ greatly from one another.	.833***		
	Mobility - Machine setups between operations are quick.	.748***		
	Uniformity - Machines are equally effective, in terms of productivity, for all operations.	.742***		
Labor Flexibility		.781***	.783	.808
	Range Number - Workers are cross-trained to perform many different tasks.	.832***		
	Range Heterogeneity - Workers can perform tasks which differ greatly from one another.	.812***		
	Mobility - A small cost is incurred (in terms of lost productivity) when workers are moved between different tasks.	.789***		
	Uniformity - Workers are equally effective, in terms of quality, for all tasks,	.717***		
Material Handling Flexibility		.787***	.761	.821
	Range Number - There are many different material handling paths between processing centers.	.772***		
	Range Heterogeneity - The material handling system can transport materials of different sizes.	.740***		
	Mobility - Changing a material handling path is quick.	.830***		
	Uniformity - The choice of material handling path does not affect the efficiency of material transfer.	.794***		
Mix Flexibility		.786***	.833	
	Range Number - A large number of product lines are produced in the firm.	.764***		
	Range Heterogeneity - The processing requirements for the products produced in the plant vary greatly from one product to another.	.754***		
	Mobility - The product mix produced by the plant can be changed easily.	.789***		
	Uniformity - The efficiency of the production process is not affected by changes in product mix.	.792***		
Modification Flexibility		.751***	.883	
	Range Number - A large number of product are modified to customer's specification.	.845***		
	Range Heterogeneity – Product modifications made are fairly similar to one another.	.793***		
	Mobility – Modified products can be made quickly.	.885***		
	Uniformity – Productivity levels are not affected when a modified product is introduced into the manufacturing system.	.801***		

[a] Please indicate the extent to which you agree or disagree with the following (1 = *strongly disagree* to 5 = *strongly agree*).
[b] Please indicate the extent to which you agree or disagree with the following (1 = *strongly disagree* to 5 = *strongly agree*).
[c] Relative to your competitors please indicate the extent to which your firm is flexible on the following areas (1 = *strongly disagree* to 7 = *strongly agree*).

Table A2
Confirmatory and discriminant analysis.

(a): Confirmatory factor analyses and alternative measurement model specification[a]

	χ^2(df)	$\Delta\chi^2(\Delta$df)	CFI	TLI	RMSEA	RMSR
Recommended values	<3.0		>.9	>.9	.05–.08	<0.03
Hypothesized Performance Measurement Model	1307.53 (1005)		.956	.943	.037 (90% C.I.: 0.011, 0.063)	0.019
Five-component manufacturing flexibility	1495.72 (1020)	188.19 (15)[***]	.846	.835	.195 (90% C.I.: 0.182, 0.208)	0.108
Product and Process Modularity as a second-order construct	1306.31 (1003)	1.22 (1)	.819	.805	.213 (90% C.I.: 0.124, 0.302)	0.117
Five-component manufacturing flexibility and Product and Process Modularity as a second order construct	1430.67 (1021)	123.14 (16)[***]	.841	.827	0.191 (90% C.I.: 0.186, 0.197)	0.101

(b): Assessment of discriminant validity

Dimensions model	Constrained χ^2 (df)	Unconstrained χ^2 (df)	$\Delta(\chi^2)$
Product modularity (AVE = .609)			
Process Modularity (AVE = 0.571)	71.223 (28)	66.198 (27)	5.025[*]
Manufacturing Flexibility (AVE = .689)	691.071 (351)	672.192 (350)	18.879[***]
Process modularity			
Manufacturing Flexibility	822.101 (475)	807.953 (474)	14.148[***]

(c): Manufacturing Flexibility – Second-order Factor Validity

Model	χ^2(df)	Normed χ^2	TLI	CFI	RMSEA
Model 1 (one-factor model)	576.205 (170)	3.389	.759	.754	.245
Model 3 (six correlated factors)	394.621 (155)	2.546	.807	.806	.192
Model 4 (second order factor)	310.602 (150)	2.071	.919	.935	.062

[***] $p < 0.001$.

[a] For all the analyses in the current study, the Robust Weighted Least Squares (RWLS) procedure is used because it is prone to fewer errors resulting from a smaller sample size and non-normal data. All analyses were conducted in Mplus 4.21 unless stated otherwise.

Table C1
Alternate model comparison.

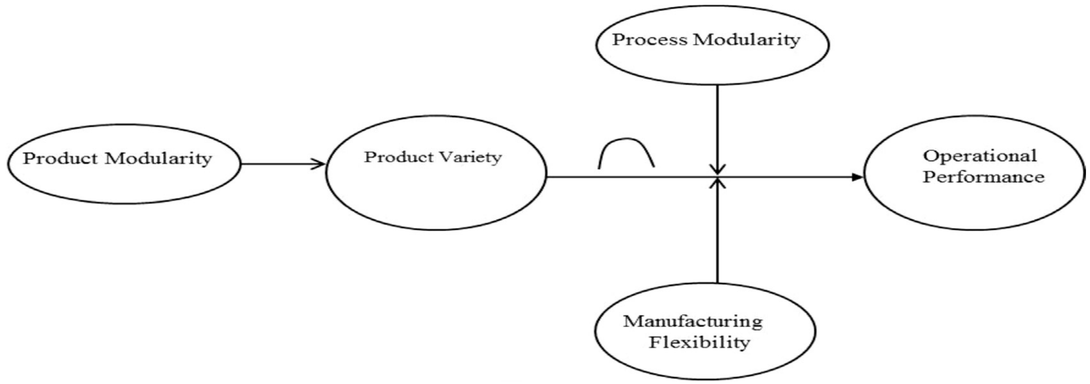
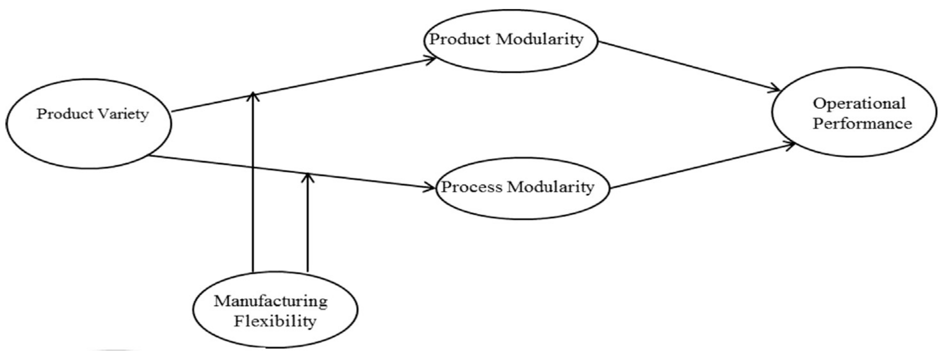
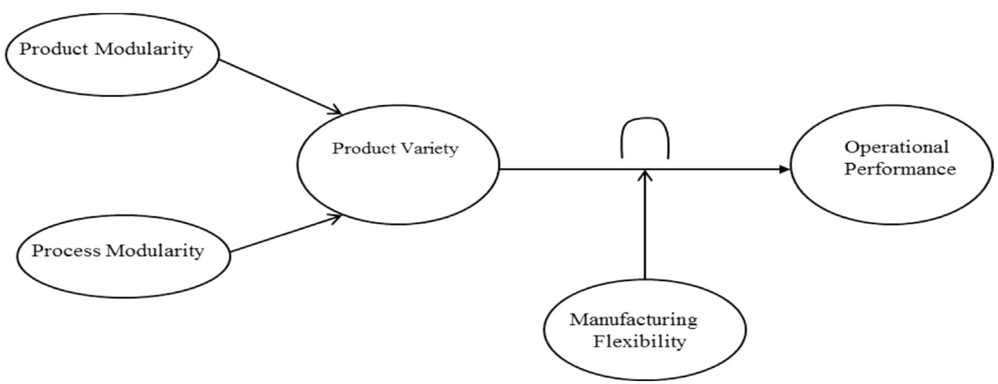
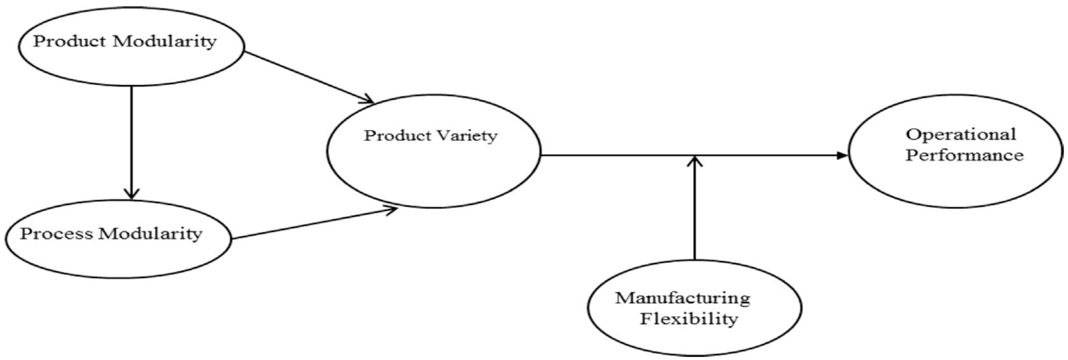
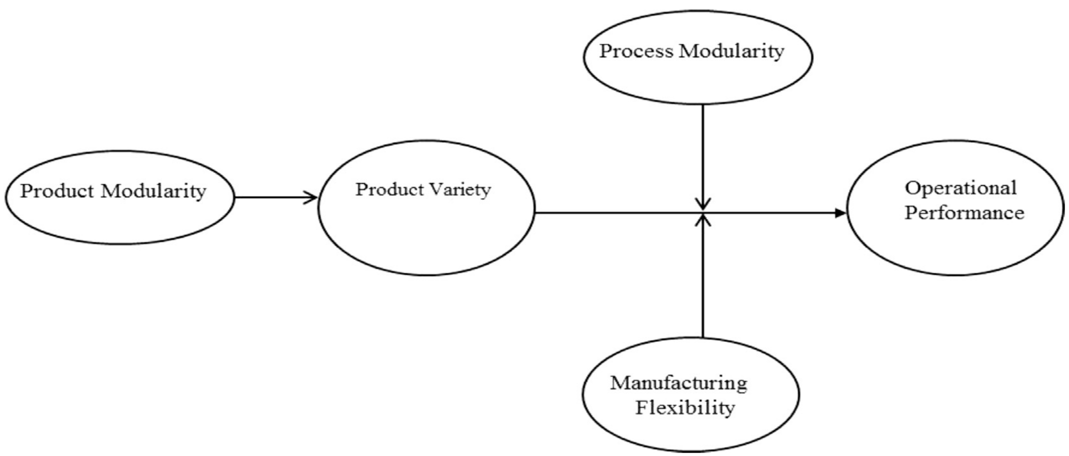
Alternate models	Model	χ^2 (df)	$\Delta\chi^2$ (Δdf)	CFI	TLI	RMSEA	RMSR
Recommended values		<3.0		>.9	>.9	.05-.08	<0.03
Model 1: Hypothesized performance measurement model		1385.64 (994)		.934	.926	.039 (90% C.I.: 0.010, 0.064)	0.022
Model 2: Product variety to product and process modularity moderated by manufacturing flexibility		1401.33 (993)	18.69 (1)	.871	.864	.142 (90% C.I.: 0.117, 0.167)	0.113
Model 3: Model 1 with process modularity moderating relationship between PPB and Performance		1394.26 (994)	8.620 (0)	.853	.846	.162 (90% C.I.: 0.127, 0.197)	0.115

Table C1 (*Continued*)

Alternate models	Model	χ^2 (df)	$\Delta\chi^2$ (Δdf)	CFI	TLI	RMSEA	RMSR
Model 4: Model 1 with link from product modularity to process modularity		1393.26 (993)	7.620 (1)	0.872	0.864	0.133 (90% C.I.: 0.105, 0.161)	0.118
Model 5: Model 1 without non-linear effects		1394.46 (995)	8.82 (2)	0.883	0.872	0.172 (90% C.I.: 0.141, 0.202)	0.136

product modularity could require increased process modularity (cf. Hoetker, 2006). Changes made in product modules will affect how the different parts of the product are assembled or "processed;" hence, this is a natural order of relationships. Continuing from "structure drives strategy" and propensity among ventures we sequentially develop capabilities, we test for an alternative Model 4. Due to limited improvement in model fit, similar to Models 2 and 3, this model was also eliminated ($\Delta\chi^2 = 7.620$; $\Delta df = 1$; $p < 0.001$; CFI = 0.872; TLI = 0.864; RMSEA = 0.133; RMSR = 0.118).

Finally, in Model 5, we tested whether Model 1 without non-linear effects provided a better fit. Because ventures face liabilities of newness and smallness, they may not reach very high product variety levels; therefore, the inverted-U relationship between product variety and operational performance may not be present. In other words, liabilities of smallness and newness could act as "range restrictions" as ventures may not be able to extend their product portfolio aggressively. As can be seen from the results, even this model did not provide a superior model fit compared to our baseline Model 1 ($\Delta\chi^2 = 8.820$; $\Delta df = 2$); $p < 0.001$; CFI = 0.883; TLI = 0.872; RMSEA = 0.172; RMSR = 0.136). Hence, Model 1 was retained as the model that best explains the phenomena under consideration.

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