Linking product modularity to supply chain integration and flexibility

Wang, Z., & Zhang, M. (2019). Linking product modularity to supply chain integration and flexibility. *Production Planning & Control*. https://doi.org/10.1080/09537287.2019.1700571

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Abstract

This study builds a moderated mediation model to empirically investigate the impacts of product modularity and supply chain integration (i.e., supplier, customer, and internal integration) on the flexibility and moderating effects of the product life cycle (i.e., growth and maturity stages) on the relationships using data collected from 204 Chinese manufacturers. The findings reveal that both supplier integration and internal integration mediate the relationship between product modularity and flexibility. Moreover, the indirect effect of product modularity on flexibility through supplier integration is stronger during the growth stage than during the maturity stage. There is no difference in the indirect effect of product modularity on flexibility through internal integration, which is significant in both the growth and maturity stages. In addition, the impact of product modularity on customer integration is significantly stronger, whereas that of customer integration on flexibility is significantly weaker during the growth stage than during the maturity stage.

Keywords: product modularity, supply chain integration, flexibility, product life cycle

1. Introduction

The importance of product modularity to improving flexibility and mass customizing solutions has been widely acknowledged by academics and practitioners (Tu et al. 2004; Salvador et al. 2007; Jacobs et al. 2007; Zhang et al. 2019). Manufacturers are implementing modularity and supply chain integration (SCI) simultaneously, enabling them to respond to market environments quickly and efficiently (Huo 2012; Wang et al. 2014). For example, Haier, which is a Chinese consumer electronics and home appliances manufacturer, recently launched the COSMOPlat platform. Based on modularization and digitalization, the platform integrates various suppliers and customers to provide mass customized products and services, greatly improving the company's flexibility. Researchers have argued that the positive effects arising from the use of common modules are due to the coordination of multiple functions within manufacturers and the collaboration between suppliers and customers (Howard and Squire 2007; Frandsen 2017).

Empirical findings about the relationships between product modularity and SCI have been quite diverse (Howard and Squire 2007; Lau et al. 2010b). One possible reason for this diversity is that most of the existing studies have failed to apply a holistic perspective to SCI (Howard and Squire 2007; Lau et al. 2010a; Danese and Filippini 2010; Sohail and Al-Shuridah 2015; Jacobs et al. 2007). Researchers have also proposed that contingent factors might be another reason for the inconsistent findings regarding the relationship between product modularity and SCI and their joint effects on performance outcomes (Lau et al. 2010b; Pero et al. 2015). Therefore, it is necessary to empirically investigate how product modularity and different types of SCI (Flynn et al. 2010) jointly affect performance outcomes (Randall and Ulrich 2001; Mikkola and Skjott-Larsen 2004; Hao et al. 2017) and how these relationships are influenced by contingencies. Product life cycle (PLC) represents the costs and sales of product forms, extending from the time when they are first placed on the market until they are removed (Rink and Swan 1979; Day 1981). It has been viewed as a fundamental variable affecting the profitability of business strategies, and it can act as a moderating variable through its influences on the value of market share position (Anderson and Zeithaml 1984).

This study aims to empirically explore how the joint effects of product modularity and SCI on flexibility are influenced by PLC. We build a model to examine the indirect effects of product modularity on flexibility through SCI and the moderating effects of PLC on the indirect effects. To develop a comprehensive understanding of the roles of different types of SCI, we simultaneously consider supplier, customer, and internal integration, which represent different capabilities (Flynn et al. 2010; Huo 2012). We introduce PLC as a moderator of modularity-SCI-flexibility relationships. This study contributes to the literature by applying a holistic perspective to SCI, which is conceptualized as a multidimensional construct that includes supplier, customer, and internal integration (Huo 2012). The indirect impact of product modularity on flexibility through SCI is examined to understand the distinctive roles of customer, supplier, and internal integration. The findings provide insights into how to improve flexibility through product and supply chain design decisions. In addition, a moderated mediation analysis is proposed to test the contingent effects of PLC on the relationships among product modularity, SCI, and flexibility. The findings could enhance current understandings of how to develop operational capabilities through product modularity and SCI under different product-market dynamics.

2. Literature review and hypotheses

2.1 *Product modularity and SCI*

Product modularity is a product design strategy that is used to reduce complexity (Salvador et al. 2007). It is defined as the design of product architecture as a hierarchical and holistic system with interchangeable components. The degree of modularity depends on the components used, their interfaces, the character of their coupling, and the opportunity for replacement (Frandsen 2017). To achieve such a design, the functions of a product are separated, so they can be easily recombined to make changes to product attributes (Sanchez and Mahoney 1996; Mikkola and Skjott-Larsen 2004). The interfaces between the different components of the product are standardized to allow the components to be changed without interface changes (Baldwin and Clark 1997; Shamsuzzoha and Helo 2017). Product modularity is characterized by functional combination, interface standardization, and system decomposition (Salvador et al. 2007). From a design perspective, modularity facilitates a flexible system that allows for the easy combination and reconfiguration of components (Sanchez and Mahoney 1996). With modularized designs, product modification can be conducted with little effort, short lead times, and low costs by changing the components (Salvador et al. 2007; Sanchez and Mahoney 1996). Product modularity can create a common language in information exchanges both within and beyond a manufacturer's boundary, allowing manufacturers to respond to customer demands flexibly (Mikkola and Skjott-Larsen 2004; Shamsuzzoha and Helo 2017). The modular design enables manufacturers to easily disassemble and reassemble functional units and/or components (Baldwin and Clark 1997). It also reduces the level of complexity for supply chain collaboration (Pero et al. 2010). It has been suggested that product modularity can facilitate communications and coordination along supply chains (Jacobs et al. 2007) and therefore is a precondition for developing operational capabilities (Droge et al. 2012; Wang et al. 2014; Zhang et al. 2019).

SCI can be defined as the degree to which a manufacturer collaboratively manages intra- and interorganizational processes (Flynn et al. 2010; Zhang et al. 2018). SCI is a multidimensional construct that usually includes external (i.e., customer and supplier) and internal integration (Flynn et al. 2010; Alfalla-Luque et al. 2013). Customer/supplier integration refers to communications and interactions between a manufacturer and customers/suppliers and the participation of customers/suppliers in a manufacturer's internal operations (Koufteros et al. 2005). Internal integration refers to the teamwork and participation of multiple functions in decision making (Koufteros et al., 2005; Zhang et al. 2018). The goals of SCI are to stimulate creativity and effectively address the interdependencies that exist among product, process, and supply chain design decisions (Petersen et al. 2005; Alfalla-Luque et al. 2013). It has been found that SCI contributes to new product development (NPD) and product and company performance (Koufteros et al. 2005; Tracey 2004). SCI can align objectives, prevent conflicts, and clarify the interpretations of goals and tasks among internal and external stakeholders (Koufteros et al. 2005; Flynn et al. 2010). Involving multiple stakeholders in operations is helpful for identifying possible design problems (Petersen et al. 2005). In addition, the expertise of different departments among manufacturers and external supply chain partners can be combined to create new knowledge (Zhang et al. 2018), allowing the manufacturer to rapidly introduce new products and provide a broad product line (Tracey 2004).

The relationship between product modularity and SCI has been investigated in the literature, and various findings have emerged from these studies (Table 1). Most studies have suggested that SCI plays an intervening role between product modularity and performance outcomes (Danese and Filippini 2013; Droge et al., 2012; Zhang et al. 2019; Mikkola and Skjott-Larsen 2004). These studies have argued that SCI is an underlying mechanism through which the operational benefits of product modularity are achieved (Jacobs et al. 2007). The literature has also indicated that there is a complementary effect of product modularity and SCI on the facilitation of operational capability development. For example, Danese and Filippini (2010) find that the interaction between product modularity and internal integration is significantly related to NPD time performance. Therefore, product modularity is significantly correlated with SCI, and they jointly affect performance outcomes (Lau et al. 2010b; Danese and Filippini 2013; Davies and Joglekar 2013). With a few exceptions (Zhang et al. 2019), a holistic perspective is not applied when investigating the relationship between product modularity and SCI. Several empirical studies have focused on either supplier integration (Howard and Squire 2007; Salvador and Villena 2013), internal and supplier integration (Jacobs et al. 2007; Lau et al. 2010a) or supplier and customer integration (Droge et al. 2012).

In addition, the conditions influencing the modularity-SCI relationship have not been well investigated. The limited evidence on this issue is based on case studies. For example, Lau et al. (2010b) investigate the modularity-SCI relationship in five NPD projects and find that the relationship is influenced by new module development, technological knowledge leakage/creation, project team size, and supply chain efficiency. Pero et al. (2015) analyze five cases in the construction and shipbuilding industries and suggest that some product (customization, innovativeness, and product size) and firm characteristics (firm size and intellectual property awareness) could influence the modularity-SCI relationship.

Table 1. Relationships between product modularity and SCI

	Role of SCI	SCI dimensions	Context	Findings
Howard and Squire (2007)	Mediator	Information sharing with supplier	UK manufacturing firms in eight industries	Product modularity leads to greater supply chain collaboration through information sharing.
Jacobs et al. (2007)	Mediator	Supplier integration; design integration; manufacturing integration	First-tier suppliers of automobile original equipment manufacturers in North America	Product modularity has a direct impact on all SCI dimensions. All SCI dimensions fully mediate the relationships of product modularity with cost and flexibility. The indirect paths from product modularity to quality and cycle time are not generally supported.
Danese and Filippini (2010)	Moderator	Supplier involvement; inter-functional integration	Manufacturing plants in the mechanical, electronics, and transportation equipment industries in eight countries	Inter-functional integration moderates the relationship between product modularity and NPD time performance. No moderating effect of supplier involvement is found.
Lau et al. (2010a)	Antecedent	Information sharing; product co-development; organizational coordination	Firms in the electronics, toy, and plastics industries in HK	Product co-development and organizational coordination are directly associated with product modularity.
Lau et al. (2010b)	Correlated	Supplier integration; customer integration; internal integration	Five NPD projects in the electronics and plastics industries in HK and the PRD region	Modular design is correlated with a loosely coordinated supply chain. This relationship is contingent on new module development, technological knowledge leakage/creation, project team size, and supply chain efficiency.
Droge et al. (2012)	Mediator	Supplier integration; customer integration	First-tier suppliers of automobile original equipment manufacturers in North America	Customer integration mediates the relationship between product modularity and delivery performance. No mediation effects of supplier integration are found between product modularity and service performance (delivery and support).
Danese and Filippini	Mediator	Supplier involvement in NPD	Manufacturing plants in the mechanical, electronics, and	Supplier involvement in NPD mediates the relationships of product modularity with NPD

(2013)			transportation equipment industries in eight countries	time and product performance.
Davies and Joglekar (2013)	Interaction	Vertical integration	The solar energy supply chains in Asia, Europe, and North America	The interaction between product modularity and SCI is positively related to the market value of the supply chain.
Pero et al. (2015)	Correlated	Supplier involvement in design; customer involvement	Five cases in the construction and shipbuilding industries	Product modularity is negatively related to SCI. Some contingent factors are identified, such as customization, innovativeness, firm size, product size, and intellectual property awareness.
Zhang et al. (2019)	Mediator	Supplier quality integration; internal quality integration; customer quality integration	Manufacturing plants in the electronics, machinery, and auto-supplier industries in ten countries	Product modularity influences competitive performance indirectly through supplier and internal quality integration.

2.2 *Flexibility*

Flexibility can be defined as “the ability to change or react with little penalty in time, effort, cost or performance” (Upton 1994: 73). It reflects a manufacturer’s ability to manage changes in a timely and appropriate manner and its actions regarding environmental changes (Brozovic 2018). Therefore, flexibility plays a critical role for manufacturers to navigate complex and uncertain business environments (Zhang et al. 2003; Jacob et al. 2007). Flexibility can expedite response, save time, and maintain dependability and hence can bring competitive advantages (Slack et al. 2013). A flexible manufacturer can reconfigure resources and act swiftly according to changes in markets (Brozovic 2018; Slack et al. 2013). The range and time of change are two key features of flexibility (Upton 1994). As a multidimensional concept and according to the dimensions of change, flexibility can be conceptualized as the ability to introduce new or modified products (product flexibility), to change an operation’s level of output or activity to produce different quantities or volumes of products over time (volume flexibility), and to produce a broad range or mix of products (mix flexibility) (Upton 1994; Slack et al. 2013).

2.3 *Product life cycle*

PLC reflects the life cycle stage of a company’s major product/product line and competition dynamics in the external environment in which a manufacturer resides (Mahapatra et al. 2012). It is a well-established environmental contingent factor that influences the formation of strategy (Wang et al. 2015) and the impacts of modularity (Peng and Mu 2018). PLC denotes the stages of product-market dynamics and the evolution of product attributes and market characteristics over time (Slack et al. 2013; Wang et al. 2015) and hence plays an important role in connecting products and markets. We focus on the growth and maturity stages because modularity is a product design decision that is more relevant in these two stages (Randall and Ulrich 2001; Mahapatra et al. 2012). They have different characteristics and provide different opportunities for manufacturers. The growth stage is characterized by unclear and unstable customer requirements and has relatively more market opportunities and lower levels of competition (Mahapatra et al. 2012). The customers are early adopters; the order winners are availability and quality; and the dominant performance objectives include speed, dependability, and quality (Slack et al. 2013). In contrast, intense competition and standards are formed in industries during the maturity stage (Mahapatra et al. 2012). Product architecture and customer demands are relatively stable. The customers are the bulk of market; the order winners are low price, dependability, and supply; and the dominant performance objectives include cost and dependability (Slack et al. 2013). Manufacturers place more emphasis on production processes and less emphasis on the development of new modules during this stage. Managers also focus on improving efficiency in processes and market segmentation (Day 1981; Rink and Swan 1979).

2.4 *Hypothesis development*

We argue that product modularity improves flexibility indirectly through customer integration, and the indirect effect is moderated by PLC. Product modularity drives a manufacturer to integrate with customers because standardization of components and interfaces reduces complexity when a manufacturer interacts and communicates with customers (Huo 2012; Fang 2008). Modularized designs also facilitate customers in providing feedback and participating in NPD. Customer integration can bring a manufacturer information and knowledge about markets and customer requirements (Fang 2008; Zhang et al. 2018). It also allows a manufacturer to develop market intelligence, which helps the manufacturer to quickly introduce new products and change product mix. By thoroughly understanding customer needs and working together with customers, manufacturers can rapidly make changes to product development and production. Customer integration can bring knowledge that provides insights into how standard modules can be assembled and configured according to different customers' preferences and be improved and redesigned according to changes in market environments (Alfalla-Luque et al. 2013; Wang et al. 2014). Thus, customer integration improves flexibility (Wong et al. 2011). Product modularity enhances flexibility by facilitating a manufacturer to acquire knowledge from customers, which can be used to adjust product designs and production; thus, its impact on flexibility is transmitted by customer integration. Therefore, product modularity improves flexibility indirectly through customer integration (Droge et al. 2012).

In the growth stage, a manufacturer faces increasing market opportunities, whereas in the maturity stage, a manufacturer has a relatively stable customer base and a predictable market environment. Therefore, compared with the maturity stage, a manufacturer must collaborate with more diversified customers; hence, the complexity associated with customer integration is greater in the growth stage (Frandsen 2017). Product modularity thus plays a more important role in improving customer integration in the growth stage than in the maturity stage because it provides common interfaces and modules that allow a manufacturer to interact and cooperate with different customers efficiently and effectively using standard processes. Customer requirements and market conditions change dramatically in the growth stage (Wang et al. 2015). Responding to customers swiftly requires manufacturers to frequently adapt the design and production of modules using the knowledge acquired from customers (Lau et al. 2010a). Compared with the growth stage, a significant proportion of sales consists of repeat or replacement purchases in the maturity stage (Anderson and Zeithaml 1984); hence, a manufacturer can obtain limited new knowledge through customer integration. As a result, the value of customer integration in providing insights into how to improve product and process design quickly and efficiently is reduced during the maturity stage (Rink and Swan 1979). Customer integration hence has a stronger impact on flexibility in the growth stage than in the maturity stage (Sohail and Al-Shuridah 2015; Huo 2012; Wang et al. 2015). Thus, we propose the following:

H1: The indirect impact of product modularity on flexibility through customer integration is stronger during the growth stage than during the maturity stage.

We argue that product modularity improves flexibility indirectly through internal integration, and the indirect effect is moderated by PLC. Product modularity facilitates internal integration because reassembling common modules into different forms promotes coordination among internal functions (Jacobs et al. 2007; Zhang et al. 2018). Modular designs drive manufacturers to use cross-functional teams and meetings because standardized interfaces reduce the barriers of interactions and communications among functional departments (Huo 2012). In addition, involving employees from multiple functions in NPD ensures that a manufacturer can introduce new products and broaden product lines quickly, improving flexibility (Zhang et al. 2018). Cross-functional teams and meetings also enable a manufacturer to adjust production volume and change product mix with low costs and in a short period of time. Integration among different functions, such as marketing, manufacturing, purchasing, and product development, allows a manufacturer to quickly transform customer requirements into module production and design decisions and to adjust internal operations accordingly to respond to new market environments quickly and efficiently (Flynn et al. 2010; Shamsuzzoha and Helo 2017; Randall and Ulrich 2001). Thus, internal integration enhances flexibility (Wong et al. 2011). Product modularity enhances flexibility by facilitating the collaboration and cooperation among internal functions, smoothening operational processes; thus, its impact on flexibility is transmitted by internal integration. Therefore, product modularity improves flexibility indirectly through internal integration (Jacobs et al. 2007; Zhang et al. 2019).

In the growth stage, new players enter markets, and manufacturers must frequently improve product designs to manage market uncertainties, whereas the designs of products and modules are stable in the maturity stage (Anderson and Zeithaml 1984). Therefore, compared with the maturity stage, internal departments must frequently collaborate and cooperate to make joint decisions quickly; hence, the complexity and difficulty associated with internal integration are greater in the growth stage (Zhang et al. 2018). Product modularity thus plays a more important role in improving internal integration in the growth stage than in the maturity stage because modular designs and standardized interfaces help a manufacturer to develop procedures that improve the speed, quantity, and quality of the information and decision flows among different functions (Frandsen 2017). In the growth stage, manufacturers face unpredictable and rapidly changing market environments, and they tend to focus on product innovation and customization (Rink and Swan 1979; Mahapatra et al. 2012). Introducing new or modified products and adjusting production volume in a short period of time require interactions and collaboration among internal functions (Sorkun and Furlan 2017). Compared with the growth stage, the value of using multifunctional teams in internal operations, such as new product and module development, is reduced because products are standardized, and dominant designs have appeared in markets during the maturity stage. Internal integration hence has a stronger impact on flexibility in the growth stage than in the maturity stage (Wang et al. 2015; Wong et al. 2011). Thus, we propose the following:

H2: The indirect impact of product modularity on flexibility through internal integration is stronger during the growth stage than during the maturity stage.

We argue that product modularity improves flexibility indirectly through supplier integration, and the indirect effect is moderated by PLC. Product modularity enhances supplier integration because the use of common modules and standard base units reduces the complexity of communications and interactions with suppliers (Koufteros et al. 2005; Wang et al. 2014). Modular product designs also assist suppliers in discussing their new products with manufacturers and participating in NPD since product modularity allows a supply chain to develop standard procedures for interactions, improving the speed and quantity of the information flows between manufacturers and suppliers (Baldwin and Clark 1997; Droge et al. 2012). In addition, developing long-term relationships and maintaining frequent interactions with suppliers can provide the motivation and knowledge that allow suppliers to adapt product design and production volume in response to manufacturers' requirements quickly (Zhang et al. 2019; Wong et al. 2011). As a result, supplier integration helps manufacturers to change product mix and production volume, provide broad product lines, and introduce new or modified products quickly (Zhang et al. 2003). Supplier integration allows a manufacturer to develop a supply chain that can change the design and production of modules and products in a short lead time with low costs to respond to changes in markets (Flynn et al. 2010; Zhang et al. 2018). Thus, supplier integration enhances flexibility (Huo 2012). Product modularity enhances flexibility by facilitating manufacturers in coordinating with suppliers regarding the design of products and processes and making joint decisions with suppliers; thus, its impact on flexibility is transmitted by supplier integration. Therefore, product modularity improves flexibility indirectly through supplier integration (Danese and Filippini 2010; Droge et al. 2012; Jacobs et al. 2007; Zhang et al. 2019).

The growth stage is characterized by high market uncertainty (Rink and Swan 1979), whereas the market environments and customer requirements are predictable, and the designs of modules and product architecture are also relatively stable in the maturity stage (Wang et al. 2015). Therefore, compared with the maturity stage, product modification is more frequent, and manufacturers focus on product or process redesigns; hence, more cooperation with suppliers is needed in the growth stage (Mahapatra et al. 2012). Product modularity thus plays a more important role in improving supplier integration in the growth stage than in the maturity stage because the standardization of modules and interfaces reduces the interdependencies between modules and decouples different suppliers' production processes (Frandsen 2017), reducing the complexity and costs of the interactions and collaborations between a manufacturer and a specific supplier. In the growth stage, manufacturers face unclear and changing customer requirements, whereas products become increasingly standardized in the maturity stage. Therefore, compared with the maturity stage, acquiring resources from suppliers is more important for a manufacturer to customize or develop innovative products to profit from new market opportunities in the growth stage. Supplier integration allows a manufacturer to leverage and exploit suppliers' abilities to build a responsive supply network, allowing the manufacturer to manage uncertain market environments by adjusting supply chain operations quickly and efficiently (Flynn et al. 2010). Supplier integration also enables manufacturers to learn and develop module-specific knowledge, which can be used to change product mix and provide a broad product line (Sorkun and Furlan 2017). Supplier integration hence has a stronger impact on flexibility in the growth stage than in the maturity stage. Thus, we propose the following:

H3: The indirect impact of product modularity on flexibility through supplier integration is stronger during the growth stage than during the maturity stage.

The conceptual framework is presented in Figure 1.

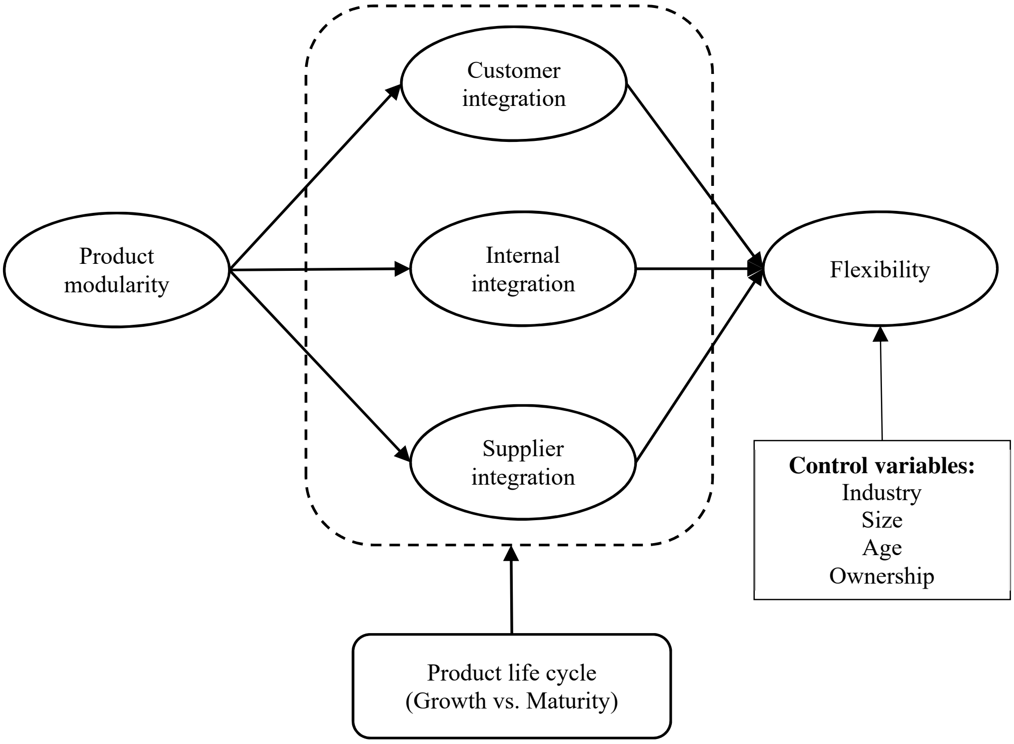


Figure 1. Conceptual model

3. Research methods

3.1 *Sample and data collection*

The survey method was used to collect data. The unit of analysis was the manufacturing company. Sample manufacturers were randomly selected from a population of manufacturers in the Pearl River Delta (PRD) region of China and who have participated in the Guangdong Provincial Technology Centre Assessment Program, which is conducted by the Industrial Research Institute. The PRD region covers nine cities in Guangdong province (i.e., Guangzhou, Shenzhen, Zhuhai, Foshan, Dongguan, Zhongshan, Jiangmen, Huizhou, and Zhaoqing). It is one of the fastest growing regions in China and has become one of the main drivers of the economy of China. The PRD region is also a major destination for foreign investment and a global manufacturing base of industrial and consumer products. As a platform for international trade, the PRD region has built a complete network for water, land, and air transportation, and it is increasingly important to global supply chains (Wang et al. 2015). The institute is responsible for evaluating the innovation capability of manufacturers. The purpose of the program is to help manufacturers improve competitiveness. Any manufacturing companies in the PRD region can apply for this program. Therefore, the sampling frame is representative of the major manufacturing industries in the PRD region. We solicited help from the professors at the institute to distribute and collect questionnaires. Selected manufacturers were contacted by phone and invited to participate in the research project. During this process, qualified respondents were identified.

In total, 745 questionnaires were distributed by mail or email (Boyer et al. 2002), and 250 questionnaires were returned. Forty-six questionnaires were removed during data cleaning. Finally, questionnaires from 204 respondents were used, and the survey achieved a 27.4% response rate. The data collection used two methods: one group including 123 samples was collected by mail, and the other group including 81 samples was collected by email. We conducted a t test to assess the response bias between the two groups (Boyer et al. 2002). There was no significant difference in the number of employees ($t = 0.889$, $p > 0.1$). We assessed the non-response bias by comparing the early and late responses. There was no significant difference in the numbers of employees between the 127 early responses and the 77 late responses ($t = 0.275$, $p > 0.1$). Approximately 88% of the respondents were managers and directors. The remaining respondents were responsible for managing the daily operations of the engineering, marketing, or manufacturing departments. The positions of respondents are shown in Table 2. In addition, all of the respondents had at least two years of working experience in their current positions. A pilot study of 10 manufacturers in the PRD region showed that they were qualified respondents for this study. The profiles of the responding manufacturers are shown in Table 3.

Table 2. Respondent profiles

Positions	N	%
Manufacturing manager	48	23.6
Supply chain manager	10	4.9
R&D manager	46	22.5
Vice president	5	2.5
Director	39	19.1
General manager	30	14.7
Others	26	12.7

Table 3. Company characteristics

	N	%		N	%
1. Industry			2. Number of employees		
Appliance	26	12.7	Fewer than 100	10	4.9
Non-metallic mineral	26	12.7	101-500	42	20.6
Fabricated metal	23	11.3	501-1000	51	25.0
Automotive	20	9.8	1001-5000	74	36.3
Chemical and pharmaceutical	24	11.9	More than 5000	27	13.2
Industrial machinery and equipment	19	9.3	3. Ownership		
Computer and electronics	17	8.3	State owned	33	16.2
Food and beverage	12	5.9	Privately owned	97	47.5
Rubber and plastic	10	4.9	Foreign owned	52	25.5
Textile and apparel	8	3.9	Joint venture	22	10.8
Other	19	9.4			

3.2 *Measures*

The measures were adapted based on the existing literature. The scales used in this study were originally developed in English and were translated into Chinese by an operations management professor. According to the steps suggested in Flynn et al. (2010), the translation was initially reviewed by another operations management professor, and then the Chinese translation was back-translated into English to compare it with the original English version for any discrepancies. Due to language differences, slight modifications were made to the wording of the Chinese version. These modifications were carefully evaluated by academics and practitioners during the development of the questionnaire and pilot test, and no ambiguities were found.

Product modularity was measured using four items about using common modules in product design, which were proposed by Tu et al. (2004). The measures of SCI were adapted from Koufteros et al. (2005), Tracey (2004), and Fang (2008). Customer integration was gauged by four items about maintaining close interactions and working together with customers. Supplier integration was measured using another four items about maintaining long-term relationships and close communications with suppliers. We used four items related to the implementation of cross-functional teams and meetings to measure internal integration. Five items were used to measure product (modifying product designs and introducing new products quickly), volume (changing production volume quickly), and mix (changing product mix quickly and providing a broad product line) flexibility, which were adapted from Zhang et al. (2003) and Jayaram et al. (2011). We used a seven-point Likert scale (1= "totally disagree"; 7= "totally agree") to capture the perceptions of the respondents to measure these constructs. The measurement items are listed in Table 4. PLC was measured by a categorical variable. The respondents were asked to judge the product-market dynamics of their main products and to select the most appropriate life cycle stage (Mahapatra et al. 2012). The question asked was: "What stage of the product market life cycle are your main products in?" We included four control variables (industry; ownership; size, which was measured by the log-transformation of the number of employees; and age, which was measured by years of operations) in the analysis. The industry and ownership were measured by dummy variables.

Table 4. Measurement model

Measurement Items	Factor Loading
Product modularity ($\alpha = 0.862$, C.R. = 0.904, AVE = 0.704)	
Our products use a modularized design	0.867

Our products share common modules	0.678
Product modules can be reassembled into different forms	0.922
Product feature modules can be added to a standard base unit	0.858
Customer integration (α = 0.828, C.R.= 0.886, AVE = 0.660)	
Our customers provide feedback or complaints about quality and delivery	0.814
Our customers are actively involved in our product design	0.811
Our customers work with us to jointly analyze the reasons for quality problems	0.858
We have close communications with key customers, including exchange visits	0.765
Supplier integration (α = 0.874, C.R.= 0.914, AVE = 0.726)	
We build long-term relationships with suppliers	0.806
We maintain close communications with suppliers regarding product quality and design modifications	0.858
Our suppliers actively discuss their new products with us	0.863
We often discuss with suppliers how to use their products	0.878
Internal integration (α = 0.724, C.R.= 0.828, AVE = 0.546)	
We usually use cross-functional teams or project teams (e.g., quality teams)	0.792
We usually organize cross-functional meetings to discuss product and process improvement	0.756
When we develop new products or modify a product's design, all of the related departments participate if possible	0.730
When we develop new products, engineers in the manufacturing department participate if possible	0.674
Flexibility (α = 0.870, C.R.= 0.906, AVE = 0.660)	
Our company is able to quickly modify product designs	0.864
Our company is able to quickly introduce new products	0.855
Our company is able to change volume in a short period of time	0.805
Our company is able to change the product mix in a short period of time	0.832
Our company is able to provide a broad product line	0.693

Note: α: Cronbach's alpha; C.R.: composite reliability; AVE: average variance extracted. All of the factor loadings are significant at $p < 0.05$.

Because a single respondent method was used for the data collection, common method bias could be a concern. Following Podsakoff et al. (2003), we used different instructions for different scales. In addition, the items were placed in different sections of the questionnaire to reduce respondents' potential consistency. Harman's single factor test was used by including all of the items in a principal component factor analysis. No significant common method bias was found because no single factor explained most of the covariance (Podsakoff et al. 2003). We further introduced a method factor to evaluate the common method bias. We built a model using partial least squares structural equation modeling (PLS-SEM) in which all of the items are loaded on their original constructs and the common method factor (Podsakoff et al. 2003). The purpose of this method is to calculate the amount of variance from each item that belongs to the common method factor (Podsakoff et al. 2003). The results show that the average variance explained by the common method is only 0.93%, and the original variance is 71 times the method variance, indicating that common method bias is not a serious concern in this study. The correlation matrix was also checked, and the highest correlation was 0.620. As suggested by Pavlou et al. (2007), common method bias is not significant if there are no excessively high correlations.

4. Analysis and results

PLS-SEM was used to test the model. It simultaneously assesses the quality of the constructs and the proposed relationships between the constructs (Hair et al. 2013). Sample size and model complexity are the main reasons for choosing PLS-SEM (Peng and Lai 2012). We propose a model including both mediation and moderation analyses, significantly increasing the model complexity and hence the requirement of the sample size. However, there are fewer than 100 observations in each sub-sample when conducting moderation analysis. The sample size is only adequate for PLS-SEM, which can provide reliable parameter estimations with small samples (Peng and Lai 2012; Hair et al. 2013). Smart PLS software (3.2.1 version) was used to assess the measurement and structural models (Ringle et al. 2015).

4.1 *Reliability and validity*

Confirmatory factor analysis was conducted to examine the measurement model (Ringle et al. 2015). The results are presented in Table 4. All of the item loadings are greater or slightly less than 0.7 and are significant at the $p < 0.05$ level. Reliability was assessed in terms of Cronbach's α and composite reliability (Fornell and Larcker 1981). The composite reliabilities ranged from 0.828 to 0.914, and Cronbach's α ranged from 0.724 to 0.874. Both are greater than the recommended threshold value of 0.70 (Fornell and Larcker 1981), suggesting adequate reliability. Convergent validity was assessed using the average variance extracted (AVE) criteria. As shown in Table 4, all AVE values are greater than 0.5 (ranging from 0.546 to 0.726), indicating adequate convergent validity. Discriminant validity was assessed by comparing the square root of the AVE of each construct to its correlation with the other constructs. The descriptive statistics of the constructs are presented in Table 5, which shows that no correlation is greater than the square root of the AVE, indicating satisfactory discriminant validity of all of the constructs.

Table 5. Correlations, means, and standard deviations

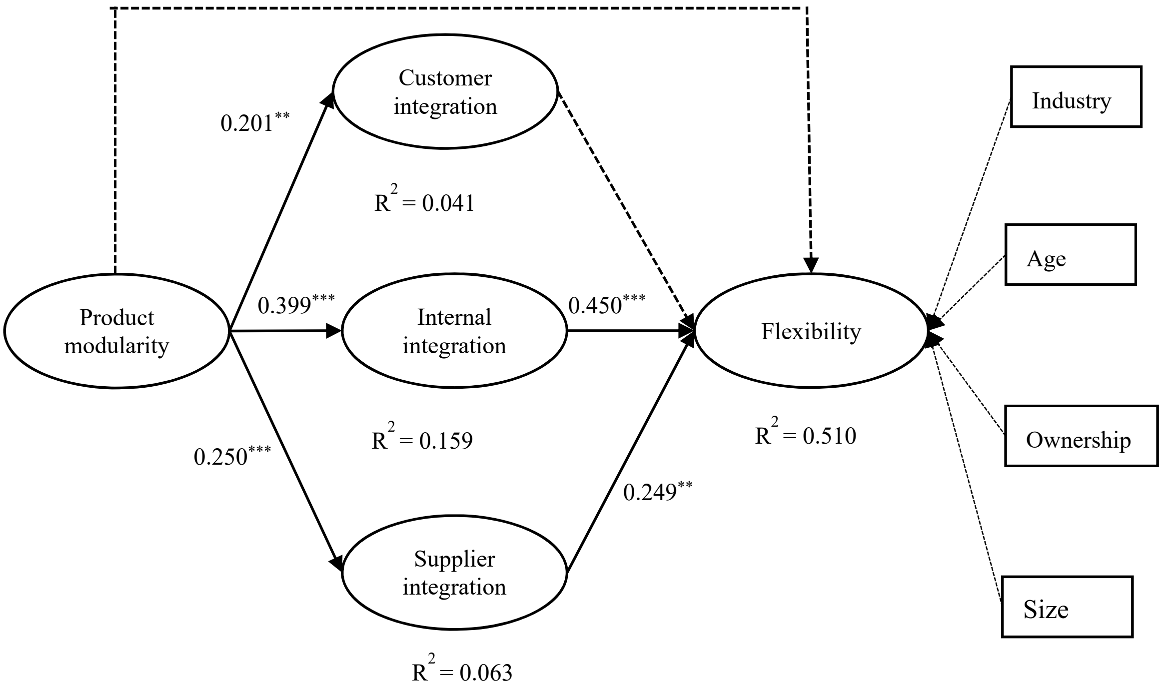
	Mean	S.D.	1	2	3	4	5
1. Product modularity	4.413	1.322	0.839				
2. Customer integration	5.782	0.925	0.176^{*}	0.813			
3. Supplier integration	5.898	0.941	0.228^{**}	0.608^{**}	0.852		
4. Internal integration	5.495	0.939	0.370^{**}	0.463^{**}	0.620^{**}	0.739	
5. Flexibility	5.547	0.977	0.203^{**}	0.416^{**}	0.580^{**}	0.615^{**}	0.812

Note: The square root of the AVE is shown on the diagonal; * $p < 0.05$; ** $p < 0.01$

4.2 *Hypothesis testing*

PLS-SEM was used to test the relationships among product modularity, SCI, and flexibility. The results are presented in Figure 2. The R^2 (0.510) indicates that the model has moderate predictive power (Peng and Lai 2012). We find that the direct impact of product modularity on flexibility is not significant. We also find that product modularity significantly improves customer ($b = 0.201$, $p < 0.01$), internal ($b = 0.399$, $p < 0.001$), and supplier integration ($b = 0.250$, $p < 0.001$). Both internal ($b = 0.450$, $p < 0.001$) and supplier ($b = 0.249$, $p < 0.01$) integration significantly enhance flexibility. However, the impact of customer integration on flexibility is not significant. The results also show that the effects of the control variables are not significant.

The strength and significance of the indirect effects of product modularity on flexibility through customer, supplier, and internal integration were tested using the bootstrap method and PLS-SEM (Preacher and Hayes 2008). After 5000 bootstrapped resamples, the results showed that the bias-corrected 95% confidence interval for the indirect effect of product modularity on flexibility through customer integration is [-0.012, 0.053]; through internal integration, it is [0.094, 0.266]; and through supplier integration, it is [0.016, 0.129]. Due to the inclusion of zero in the confidence interval, the indirect effect of product modularity on flexibility through customer integration is not significant (Preacher and Hayes 2008). The indirect effects of product modularity on flexibility through internal and supplier integration are significant.



*p < 0.05, **p < 0.01, ***p < 0.001

Figure 2. Results of structural model

To test the moderating effects of PLC, the sample was separated into two sub-samples according to PLC (i.e., growth and maturity stages). There are 93 manufacturers in the growth stage group and

97 manufacturers in the maturity stage group. Fourteen responses were removed from the cross-group comparison analysis because 11 manufacturers were in the decline stage, and 3 respondents did not answer the PLC question. The correlations, mean, and standard deviations of the variables in each group are shown in the Appendix. We examined the indirect effects of product modularity on flexibility through customer, internal, and supplier integration in the two groups, with their significance levels determined by the bias-corrected bootstrap method using a 95% confidence level and employing 5000 samples (Preacher and Hayes 2008). We found that the bias-corrected 95% confidence interval for the indirect effect of product modularity on flexibility through customer integration is [-0.086, 0.079]; through internal integration, it is [0.055, 0.282]; and through supplier integration, it is [0.030, 0.229] when a product is in the growth stage. In contrast, the bias-corrected 95% confidence interval for the indirect effect of product modularity on flexibility through customer integration is [-0.104, 0.051]; through internal integration, it is [0.033, 0.289]; and through supplier integration, it is [-0.055, 0.092] when a product is in the maturity stage. Therefore, the mediation effect of supplier integration is only significant when a product is in the growth stage, that of internal integration is significant in both stages, and that of customer integration is not significant in either stage. In addition, PLS-SEM multi-group analysis was used to further explore the moderating effects of PLC (Henseler 2012). The results are shown in Table 6. We find that the impact of product modularity on customer integration ($p = 0.007$) and the impacts of customer ($p = 0.048$) and supplier ($p = 0.039$) integration on flexibility are significantly different between the two groups. The findings show that product modularity only improves customer integration when a product is in the growth stage, whereas the impact of customer integration on flexibility is only significant when a product is in the maturity stage. Therefore, H1 is not supported. The results also suggest that product modularity has similarly significant and positive

effects on internal integration, and internal integration has similarly significant and positive effects on flexibility in both stages. Therefore, H2 is not supported. Moreover, the findings show that, although product modularity has similarly positive effects on supplier integration in both stages, supplier integration has a positive impact on flexibility only when a product is in the growth stage. Therefore, H3 is supported.

Table 6. Cross-group comparisons (growth stage vs. maturity stage)

Path	Growth	Maturity	Growth vs. Maturity (p value)
Product modularity → Customer integration	0.373***	-0.033$^{n.s.}$	0.007
Product modularity → Internal integration	0.376***	0.347**	0.467
Product modularity → Supplier integration	0.281**	0.181$^{n.s.}$	0.282
Customer integration → Flexibility	0.004$^{n.s.}$	0.266*	0.048
Internal integration → Flexibility	0.380**	0.422***	0.619
Supplier integration → Flexibility	0.367**	0.021$^{n.s.}$	0.039
Controls			
Product modularity → Flexibility	0.067$^{n.s.}$	0.090$^{n.s.}$	
Size → Flexibility	-0.067$^{n.s.}$	-0.059$^{n.s.}$	
Age → Flexibility	-0.073$^{n.s.}$	0.120$^{n.s.}$	
State-owned → Flexibility	-0.143$^{n.s.}$	0.077$^{n.s.}$	
Privately-owned → Flexibility	-0.113$^{n.s.}$	0.140$^{n.s.}$	
Foreign-owned → Flexibility	-0.289*	0.078$^{n.s.}$	
Appliance → Flexibility	-0.010$^{n.s.}$	0.144$^{n.s.}$	
Non-metallic mineral → Flexibility	-0.035$^{n.s.}$	0.069$^{n.s.}$	
Fabricated metal → Flexibility	-0.156$^{n.s.}$	-0.019$^{n.s.}$	
Automotive → Flexibility	-0.134$^{n.s.}$	-0.040$^{n.s.}$	
Chemical and pharmaceutical → Flexibility	0.023$^{n.s.}$	0.098$^{n.s.}$	
Industrial machinery and equipment → Flexibility	-0.065$^{n.s.}$	-0.005$^{n.s.}$	
Computer and electronics → Flexibility	0.058$^{n.s.}$	-0.086$^{n.s.}$	
Food and beverage → Flexibility	-0.110$^{n.s.}$	0.061$^{n.s.}$	
Rubber and plastic → Flexibility	0.260*	0.112$^{n.s.}$	
Textile and apparel → Flexibility	-0.110$^{n.s.}$	0.027$^{n.s.}$	

Note: n.s.: not significant, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

We further conducted a post hoc analysis by testing the research model using the covariance-based SEM method and AMOS software, version 21.0. The results are presented in Table 7. The model fit indices are Chi-square (142) = 312.98, Comparative Fit Index = 0.92, Tucker Lewis Index = 0.90, and

Incremental Fit Index = 0.92, which are acceptable (Hu and Bentler 1999). The results revealed that product modularity significantly influences customer (b = 0.160, p = 0.004), internal (b = 0.407, p < 0.001), and supplier (b = 0.186, p < 0.001) integration. Internal (b = 0.298, p = 0.001) and supplier (b = 0.452, p = 0.001) integration significantly influences flexibility. The impacts of product modularity and customer integration on flexibility are not significant. The findings are consistent with those of the PLS-SEM. In addition, we conducted a mediated regression analysis using the ordinary least squares and bootstrap methods. After 5000 bootstrapped resamples, the results showed that the bias-corrected 95% confidence interval for the indirect effect of product modularity on flexibility through customer integration is [-0.025, 0.040]; through internal integration, it is [0.093, 0.303]; and through supplier integration, it is [0.003, 0.122]. Therefore, the results are consistent with those using the PLS-SEM and bootstrap methods.

Table 7. Results of the covariance-based SEM analysis

Path	Estimate	Standard error	p value
Product modularity → Customer integration	0.160	0.056	0.004
Product modularity → Internal integration	0.407	0.078	<0.001
Product modularity → Supplier integration	0.186	0.050	<0.001
Customer integration → Flexibility	-0.060	0.109	0.583
Internal integration → Flexibility	0.298	0.091	0.001
Supplier integration → Flexibility	0.452	0.142	0.001
Product modularity → Flexibility	-0.044	0.052	0.398

5. Discussion and conclusions

5.1 *The mediating effects of SCI*

The results show that the indirect effect of product modularity on flexibility through customer integration is not significant. The analysis further reveals that this lack of significance is because the impact of customer integration on flexibility is not significant, and the indirect effect is moderated by

PLC. We argue that customer integration carries the effects of product modularity on flexibility by providing knowledge that can be used to introduce new products and to customize existing products. A manufacturer can obtain market knowledge via customer integration. However, in the growth stage, market environments are unpredictable, and manufacturers must introduce innovative products to capture new market opportunities. Although customer integration can bring a manufacturer knowledge about markets and demands, the knowledge is based on existing customers. As a result, manufacturers cannot acquire valuable knowledge that enables them to respond to new market opportunities through customer integration, which is critical for improving flexibility in the growth stage.

The results show that product modularity enhances flexibility indirectly through internal integration. Product modularity allows a manufacturer to break functional silos, and internal integration facilitates joint decision making and helps a manufacturer to develop responsive operational processes and systems. Internal integration carries the effects of product modularity on flexibility by allowing manufacturers to coordinate internal processes and operations and improving the speed, quality, and smoothness of physical and information flows. Product modularity cannot improve flexibility if internal functions are not integrated because it can take a long time for a manufacturer to transform market knowledge into production instructions and change processes accordingly.

The results show that product modularity enhances flexibility indirectly through supplier integration. Product modularity reduces the costs and complexity of supplier integration, helping a manufacturer to develop an agile and collaborative supply chain. Changing the design and production of modules requires suppliers to adjust their operations accordingly. Supplier integration carries product modularity’s effects on flexibility by allowing a manufacturer to adjust the design and production of modules quickly to fulfill new market demands. If a manufacturer does not interact and cooperate with suppliers, it cannot introduce new products or change production volume swiftly even if the manufacturer modularizes product designs because it lacks a responsive supply chain; hence, it can take a long time for the suppliers to change operations.

5.2 *The moderating effects of PLC*

The results show that customer integration plays a mixed role when transmitting the impact of product modularity on flexibility. We find that PLC significantly moderates the relationship between product modularity and customer integration and that between customer integration and flexibility. The key differences between the growth and maturity stages are that the former is characterized by unclear and unstable customer requirements, and the latter is characterized by a stable customer base and standardized products (Mahapatra et al. 2012). As a result, in the growth stage, a manufacturer must interact and collaborate with an expanding customer base. Product modularity reduces the complexity and costs of customer integration; hence, it positively influences customer integration. In the growth stage, market environments change quickly. Keeping up with demand could prove to be the main operations preoccupation, and speed is the dominant performance objective (Slack et al. 2013). Customer integration can lock a manufacturer in with existing customers. As a result, the manufacturer could become less responsive to new customer demands and market environments; hence, customer integration does not improve flexibility in the growth stage. In the maturity stage, a manufacturer has collaborated with existing customers for a relatively long time. Standard procedures have been established; hence, the complexity of customer integration is reduced. Therefore, product modularity does not significantly influence customer integration. A manufacturer must differentiate product and brand to manage the intensified competition and price drops in the maturity stage. Customer integration can provide information that enables a manufacturer to reconfigure and reassemble modules to customize products quickly for existing customers at low costs. Therefore, customer integration improves flexibility.

Internal integration has similar mediating effects in both the growth and maturity stages, suggesting that internal integration is always needed to bridge product modularity and flexibility regardless of the stage of PLC. In the growth stage, a manufacturer emphasizes introducing new or modified products, whereas in the maturity stage, a manufacturer focuses on optimizing processes to reduce overall costs (Mahapatra et al. 2012). Therefore, product modularity improves internal integration in both stages because it can decrease the costs and complexity of cross-functional collaboration on NPD and result in process improvement. In addition, internal integration facilitates the manufacturer in modifying product designs, expanding product lines and optimizing product production, improving flexibility in both the growth and maturity stages. Thus, PLC does not moderate the indirect effect of product modularity on flexibility through internal integration.

We find that the mediation effect of supplier integration is stronger when a product is in the growth stage than in the maturity stage. This result explains the inconsistent findings on the joint effects of product modularity and supplier integration (Jacobs et al. 2007; Dorge et al. 2012; Danese and Filippini 2013). The growth stage is characterized by rapidly changing market environments, and manufacturers compete over speed and quality, whereas in the maturity stage, manufacturers face intensified competition and focus on improving efficiency in operational processes to achieve low prices and to compete over overall costs (Slack et al. 2013). Therefore, in the growth stage, product modularity reduces the interdependencies among the modules produced by different suppliers, promoting supplier integration. Manufacturers focus on competing with regard to speed to profit from volatile market environments; hence, supplier integration emphasizes helping manufacturers to build responsive supply chains, which improve flexibility. In the maturity stage, operations will be expected to lower costs to maintain profits or to allow price cuts. Cost and productivity issues are likely to be the operation’s main concerns, and low prices have become the likely order winners (Slack et al. 2013). Manufacturers compete over cost to reduce prices; hence, supplier integration might emphasize improving supply chain efficiency by reducing product variety and increasing production volume to benefit from economies of scale and lean production, which can in turn negatively influence flexibility. Therefore, the indirect effect of product modularity on flexibility is reduced in the maturity stage because supplier integration does not positively affect flexibility.

5.3 *Theoretical contributions*

This study contributes to the literature in two ways. First, the findings complement the existing studies on the modularity-SCI relationship. We find that product modularity is positively associated with SCI, providing empirical evidence that modularity leads to integration. The results also reveal that the impact of product modularity on flexibility is fully mediated by internal and supplier integration, which enhances existing knowledge on the mechanisms through which product modularity contributes to performance outcomes. Furthermore, this study enriches the current understandings of the distinctive roles played by customer, supplier, and internal integration in realizing the benefits of product modularity to flexibility and the joint effects of product modularity and SCI on flexibility. The results suggest that researchers should consider SCI when investigating the impacts of product modularity, extending the existing knowledge on the complex modularity-SCI-flexibility relationships.

Second, the contingency effect of PLC is explored in this study. We develop a moderated mediation model, and the findings provide a deeper understanding of the relationships among product modularity, SCI, flexibility, and PLC. A few case studies have suggested that contingencies influence the relationships between product modularity and SCI (Lau et al. 2010b; Pero et al. 2015). This study draws attention to PLC, which specifies the conditions under which decisions related to modularity and SCI are made. It also provides insights into the factors influencing the impact of SCI on performance outcomes (Wong et al. 2011; Zhang et al. 2018). The empirical study provides solid evidence that PLC is an important contingency that influences modularity-SCI-flexibility relationships. The results show that PLC plays different roles in influencing the joint effects of product modularity and customer, internal, and supplier integration on flexibility. The analysis finds that the indirect impact of product modularity on flexibility through supplier integration is stronger during the growth stage than during the maturity stage. The findings further reveal that the impact of product modularity on customer integration and that of customer and supplier integration on flexibility are moderated by PLC. The study enhances existing knowledge about the influences of product-market dynamics on the relationships among product modularity, SCI, and flexibility, and it provides a possible explanation for the inconsistent conclusions regarding the relationships. The results suggest that a contingent perspective should be adopted when investigating the joint effects of product modularity and SCI on flexibility. To fully capture the benefits of product modularity to performance outcomes, researchers should consider product-market dynamics and SCI at the same time.

5.4 *Managerial implications*

Overall, the findings inform managers by showing that the realization of the benefits of modular design depend on SCI and PLC. We find that product modularity enhances flexibility indirectly through supplier and internal integration. We thus suggest that managers use a modularized product design and common modules across product lines to improve product, mix, and volume flexibility. In addition, managers should be aware that, to materialize the benefits of product modularity, they must integrate internal functions and with suppliers at the same time. For example, we recommend that managers use cross-functional teams in internal operations and involve employees from multiple departments in NPD. Managers should also build long-term relationships with suppliers, maintain close communications with suppliers regarding product quality and design modifications, and discuss with suppliers how to use their products.

We recommend that managers consider the stage of PLC to fully reap the benefits of product modularity and SCI to flexibility. When a product is in the growth stage, managers should be aware that supplier integration and internal integration improve flexibility and carry product modularity's effects; hence, manufacturers should invest in product modularity and supplier and internal integration simultaneously. We find that the mediation effect of supplier integration is stronger during the growth stage than during the maturity stage and that customer integration enhances flexibility in the maturity stage. Therefore, when managers observe that sales volume, profit, and competition begin to increase, we suggest that manufacturers modularize products and integrate with suppliers through information sharing, process synchronization, and the building of long-term relationships, whereas when managers find that sales volume peaks, market saturation is reached, and prices tend to drop due to the proliferation of competing products, managers should invest in customer integration. For example, manufacturers should maintain close communications with key customers and acquire their feedback and suggestions. Manufacturers should also work with customers on NPD, problem solving, and quality improvement. In addition, the results show that product modularity enhances flexibility through internal integration in both the growth and maturity stages, and the mediation effects are not significantly different. As a result, when a product is in the maturity stage, we suggest that managers continuously implement the procedures and practices adopted in the growth stage to facilitate interactions and collaboration among internal departments. For example, manufacturers should use project teams and organize cross-functional meetings to discuss product and process improvement. Representatives from multiple departments should be involved when developing new products or modifying product designs. Moreover, a manufacturer should focus on product modularity and internal and customer integration at the same time to leverage their impacts on flexibility in the maturity stage. For example, a manufacturer should design products using common modules and standard base units, while customers should be involved in the cross-functional meetings when developing new products and solving problems. Multi-functional teams should also be formed to interact with customers, and the information obtained from customers should be incorporated into product and process improvement decisions.

5.5 *Limitations and future research directions*

Although this study contributes to understanding of modularity-SCI-flexibility relationships, it has limitations that suggest opportunities for future research. First, a cross-sectional design is used in this study. A longitudinal design could help to establish causality among the modularity, SCI, and performance outcomes. Second, only product modularity is considered in this study. Future research could extend the study by introducing other modularity strategies, such as process and supply chain modularity (Tu et al. 2004). Third, PLC is defined at the product level, whereas the data are collected from manufacturing companies, which is a limitation. Fourth, the findings are based on a sample of Chinese manufacturers. Although this study uses a random sampling method, the sample is selected from a specific region and only includes manufacturers who participated in a technology assessment program. This method could lead to sample bias, which would undermine the external validity of the findings. Care should be taken when generalizing the findings to other contexts. Future studies could test the model in other countries with different business and institutional environments to validate the findings.

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Appendix. Correlations, means, and standard deviations in the growth and maturity stages

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Product modularity		-.059	.137	.311**	.156	.041	-.106	.039	.095	-.190	.157	-.068	.044	.075	-.175	.047	.017	.013	-.036	-.184
2. Customer integration	.342**		.658**	.461**	.482**	.087	.042	-.011	-.049	-.007	-.195	.235*	-.013	-.011	.014	-.154	.119	.127	-.086	.003
3. Supplier integration	.264*	.550**		.655**	.528**	.034	.000	-.094	.208*	-.236*	-.150	.171	.094	-.037	.065	-.133	.040	.188	-.037	-.064
4. Internal integration	.347**	.450**	.551**		.587**	.169	.130	-.145	.059	-.066	-.200*	.119	.103	-.005	.059	-.050	.026	.045	-.070	-.055
5. Flexibility	.181	.406**	.600**	.597**		.047	.160	-.070	.119	-.102	.005	.142	.000	-.048	.072	-.110	-.095	.083	.045	-.009
6. Size	.180	.237*	.109	.203	.124		.235*	.131	-.122	.045	-.150	.159	-.090	-.112	-.048	-.064	.130	-.070	-.054	.001
7. Age	-.082	.011	.152	.154	.030	.158		.107	.093	-.143	-.049	-.085	.156	.162	-.131	-.051	-.030	-.062	.035	.170
8. State-owned	-.167	-.130	-.026	-.074	-.155	.229*	.342**		-.415**	-.245*	-.095	.027	-.001	.029	.027	-.137	-.039	.029	.088	-.110
9. Privately owned	-.053	.063	.113	-.029	.178	-.070	-.075	-.458**		-.556**	.248*	.044	.042	.054	-.021	-.026	-.097	-.226*	-.054	.094
10. Foreign owned	.231*	-.060	-.098	-.018	-.173	-.209*	-.151	-.255*	-.523**		-.168	-.054	-.085	-.134	-.054	.064	.228*	.190	.036	.051
11. Appliance	.202	-.028	.057	.159	.110	.062	-.015	-.173	.112	.121		-.147	-.162	-.096	-.147	-.131	-.131	-.096	-.073	-.105
12. Non-metallic mineral	-.117	.006	.017	.039	.083	-.022	.018	-.110	.106	-.218*	-.148		-.141	-.083	-.128	-.114	-.114	-.083	-.064	-.092
13. Fabricated metal	.071	-.030	.003	-.047	-.163	-.181	.045	.127	-.026	-.003	-.120	-.132		-.092	-.141	-.126	-.126	-.092	-.070	-.101
14. Automotive	.132	-.103	-.085	-.130	-.200	.081	-.149	.190	-.167	-.012	-.154	-.170	-.138		-.083	-.075	-.075	-.054	-.042	-.060
15. Chemical and pharmaceutical	-.253*	.018	-.127	.025	.028	-.146	-.098	-.061	-.026	.084	-.120	-.132	-.107	-.138		-.114	-.114	-.083	-.064	-.092
16. Industrial machinery and equipment	.127	.087	.013	.120	.013	-.044	.099	.033	.047	-.003	-.120	-.132	-.107	-.138	-.107		-.102	-.075	-.057	-.082
17. Computer and electronics	.015	.053	.128	.058	.126	.097	-.054	.134	-.135	.099	-.087	-.096	-.078	-.100	-.078	-.078		-.075	-.057	-.082
18. Food and beverage	.117	.131	.221*	.044	.019	.132	.154	.076	-.113	-.057	-.104	-.115	-.093	-.120	-.093	-.093	-.068		-.042	-.060
19. Rubber and	-.189	-.121	-.177	-.314**	.084	.033	-.007	-.011	.096	-.037	-.096	-.106	-.086	-.111	-.086	-.086	-.063	-.075		-.046

plastic																				
Growth stage																				
Mean	4.720	5.890	6.020	5.684	5.696	3.37	23.289	.183	.484	.226	.118	.140	.097	.151	.097	.097	.054	.075	.065	.022
Standard deviations	1.298	.942	.900	.891	.959	1.071	9.782	.389	.502	.420	.325	.349	.297	.360	.297	.297	.227	.265	.247	.146
Maturity stage																				
Mean	4.180	5.740	5.855	5.369	5.431	3.33	25.384	.155	.485	.247	.144	.113	.134	.052	.113	.093	.093	.052	.031	.062
Standard deviations	1.306	.850	.928	.943	.932	1.106	9.396	.363	.502	.434	.353	.319	.342	.222	.319	.292	.292	.222	.174	.242

Note: The upper triangular matrix shows the correlations among variables in the maturity stage, and the lower triangular matrix shows the correlations among variables in the growth stage.

* $p < 0.05$; **$p < 0.01$