

Article

# Knowledge Creation Process and Sustainable Competitive Advantage: the Role of Technological Innovation Capabilities

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**Abstract:** This study examines the relationship between the knowledge creation process and technological innovation capabilities, and analyzes their effect on a firm's sustainable competitive advantage using a knowledge-based view theoretical framework. We conduct structural equation modeling analyses using survey data from 315 Chinese industrial firms to test the direct and indirect effects of the knowledge creation process on sustainable competitive advantage. Technological innovation capabilities—operationalized to reflect the dimensions of process innovation capability and product innovation capability—are used as the mediating variable for explaining the relationship between the knowledge creation process and sustainable competitive advantage. The results indicate that the knowledge creation process does not have a significant direct effect on sustainable competitive advantage. Rather, the knowledge creation process can only influence the sustainable competitive advantage through the mediating effect of technological innovation capabilities completely. Consequently, the knowledge creation process favors the development of technological innovation capabilities for processes and products, because processes and products can lead to a sustainable competitive advantage.

**Keywords:** knowledge creation process; process innovation capability; product innovation capability; sustainable competitive advantage

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## 1. Introduction

The question of what constitutes a sustainable competitive advantage (SCA) is a primary topic in current business strategy management research, and the knowledge-based view (KBV) of the source of SCA has received substantial attention. Indeed, as global competition, environmental turbulence, and the knowledge economy continue to grow, knowledge is deemed a strategic asset that enables businesses to develop a competitive edge [1]. To achieve and maintain competitiveness and sustainable growth, companies must constantly absorb existing knowledge, create new knowledge, and pursue practical wisdom [2]. Moreover, the rapid development of information technologies, such as big data and cloud computing, has promoted an exponential accumulation of social knowledge and knowledge stock; thus, being able to tap into a wealth of knowledge and information and create knowledge resources that can foster a company's development has become central to business competitiveness [3].

Numerous arguments have been proposed as to the role of a company's knowledge creation in its competitive advantage. Penrose first formulated the KBV of business competitive advantage, suggesting that the interaction between productive services and knowledge creation underlies a company's development [4]. Prahalad and Hamel attributed the source of a company's SCA to its core competencies, and defined core competencies as "the company's collective knowledge about how to coordinate diverse production skills and technologies" [5]. Leonard-Barton indicated that the knowledge a company accumulates throughout its development, particularly the tacit knowledge that is difficult for its rivals to replicate, is essential to its SCA [6]. Grant maintained that knowledge creation and utilization are essential to businesses; compared with their markets, businesses can create and expand knowledge more effectively to facilitate the application and protection of their intellectual property; business competitive advantage is based on the capability to establish a system for generating and protecting knowledge resources; and such a capability facilitates the integration of knowledge and other resources to yield economic rents that are larger than average profits [7].

Although knowledge creation has been widely recognized as the key to SCA, few studies have discussed, at the micro level, the mechanism by which a company develops this advantage when it creates knowledge [8]. This literature gap has two possible explanations. First, whether knowledge creation always leads to a SCA lacks robust evidence. Given the overriding focus of a business on profit generation, the outcomes of knowledge creation as a business behavior should be examined through input–output comparisons. Second, a SCA represents the continued competitiveness of a product or service in the market [9]. From a resource-advantage perspective, knowledge is characteristically tacit, non-dynamic, and is difficult to transfer or disseminate [7]. Therefore, businesses should create knowledge to produce innovations, such as technologies and products, thereby translating their knowledge resources into SCAs [10]. In summary, research on the mechanism in the relationship between knowledge creation and SCA formation requires greater rigor and greater depth. On the basis of recent studies, the present study used technological innovation theories to investigate how the knowledge creation process (KCP) affects SCA through process and product innovation capabilities. Employing a mediation approach offers the benefits of a more comprehensive understanding of the mechanism underlying the KCP—SCA relationship. Specifically, we firstly investigate how KCP promotes firms' technological innovation capability (technological IC) and SCA directly. Secondly, we explore the relationship between firm's technological IC and SCA. Then, we further examine whether technological IC mediates the relationship between KCP and SCA. The remainder of the paper is structured as follows: Section 2 considers the theoretical background and sets out the study hypotheses; Section 3 details the research methods; Section 4 presents the analysis and results of the empirical study; and Section 5 presents the discussion and conclusions.

## 2. Theoretical Background and Research Hypotheses

Theories on knowledge creation are largely applied to explicate the formation processes and outcomes of various types of knowledge within an organization [11]. Theoretically, models can be constructed to explore knowledge creation at an individual, group, or organizational level. Learning model types employed at the individual level are predominantly single or double-loop [12], which illustrate the criteria required to facilitate an individual's knowledge development. Generally, research into knowledge creation at the group level focuses on knowledge development and conversion, and argues for a close relationship between individual and organizational learning [13]. Studies on knowledge creation at the organizational level have suggested that we have at least two perspectives to understand the process of knowledge creation in organizations: the internal view and the ecosystem view [14]. Research studies that focused on the internal view emphasized that new knowledge begins with intuitive metaphors that link contradictory concepts [15], and may be created when prior knowledge is shared and transferred among members of an organization [16]. Thus, the internal view highlighted the crucial role of the creative and absorptive capacity of individuals within the organization [17]. Researchers that focused on the ecosystem view argued that a singular organization

is embedded in an ecosystem [14], and much knowledge creation happens between organizations or industries, or by networks of organizations including suppliers, users, competitors, universities, public research centers, etc. [18,19]. Firms have increasingly co-created knowledge with external stakeholders during the innovation process to expand their knowledge base [20], and interorganizational learning is the key to the accomplishment of knowledge co-creation process [8]. Our goals in this article are to clarify the mechanisms through which firms can establish SCA through KCP, and we adopt the opinion that a firm's SCA is mainly determined by the endogenous force from resources and capabilities [9]. Thus, our work will focus only on the internal dimension of knowledge creation. Regarding research studies from the internal perspective, the SECI model, which defines KCP as a spiral process of socialization, externalization, combination, and internalization, developed by Nonaka and Takeuchi is the most widely used model for analyzing knowledge creation [21]. Focusing on the conversion between tacit and explicit knowledge, this model divides knowledge creation into the processes of socialization, externalization, combination, and internalization, suggesting that businesses should promote conversion between their tacit and explicit knowledge to foster their innovation and development [16,21].

The SECI model defines the ranges of tacit and explicit knowledge to identify the mechanisms underlying knowledge creation. Explicit knowledge refers to knowledge that can be articulated using formal and systematic language and shared in the form of statistics, scientific formulae, specifications, and manuals [22,23]. It can be readily processed, communicated, and stored. Tacit knowledge is highly personal and difficult to codify and communicate; it is acquired through experience. Moreover, such knowledge is disseminated through activities under certain conditions and locations; acquired through observation, imitation, and practice; communicated through apprentice training and face-to-face interaction; and transferred through the movement of individuals between organizations [23]. Subjective perception, intuition, and instinct are encompassed by tacit knowledge [24,25].

The SECI model of knowledge creation is illustrated as follows. Socialization refers to the conversion between and the dissemination of tacit and explicit knowledge within an organization (i.e., the process of sharing experiences to create tacit knowledge, such as shared mental models and technical skills) [21]. Externalization is the conversion of tacit knowledge to explicit knowledge or the articulation of tacit knowledge into explicit concepts; it is the essence of knowledge creation that involves using metaphors, analogy, concepts, hypotheses, or models to explicate tacit knowledge [24]. Combination is the conversion from explicit to tacit knowledge or the organization of concepts into a knowledge system [24]. This process occurs primarily through formal education and training. Internalization is the conversion from explicit to tacit knowledge or the embodiment of explicit knowledge into tacit knowledge [25]. The current study adopted the SECI model to depict knowledge creation within organizations and explore the role of the model in SCA.

### 2.1. KCP and Technological IC

Among numerous classifications of innovations, one of the most commonly accepted is that of the OECD (Organization for Economic Co-operation and Development) in the Oslo Manual [26], which distinguishes four types of innovation: process, product, marketing, and organizational [27]. Technological innovation involves process and product innovations, whereas non-technological innovation involves marketing and organizational innovations [26]. This paper focuses on the two types of innovation that the OECD considered technological. The first, technological innovation capability for product (Product IC), refers to a firm's capability to create, design, and develop new products to satisfy customer needs [27]. Depending on its novelty, a product innovation can be either incremental or radical. Incremental innovation refers to a product with slightly altered technology, functionality, and appearance, whereas radical innovation refers to a product characterized by thorough, innovative, and distinct technical alterations [28]. The second, technological innovation

capability for process (Process IC), is the ability to improve product or work processes through technical advances [29].

The KBV states that a business is a “unique sum of heterogeneous knowledge; its primary function is to create, integrate, and utilize knowledge; and communication and interaction outside and inside the business is characteristically ‘a process of knowledge flow’” [7]. For businesses, knowledge is fundamental for undertaking technological innovation, expanding the scope of knowledge integration, and improving the ability to create knowledge; this is because knowledge contributes significantly to the improvement and technical level of products [30]. The existence of a business depends on whether it can efficiently create, apply, and commercialize knowledge related to technologies and markets [31]. Knowledge creation can be seen as explicating the knowledge of individuals in an organization into group knowledge. Therefore, knowledge creation at the individual level underpins that at the organizational level; exchanging and sharing knowledge within an organization promotes the explication, transmission, and integration of tacit knowledge within the organization. These processes internalize newly created knowledge in individual employees, thereby completing the cycle of knowledge creation [11,21]. From the perspective of knowledge stock, a business capable of creating knowledge can constantly generate the knowledge resources required to upgrade its processes and products [20,32]. This is particularly true in increasingly competitive industries, where businesses that exchange and integrate knowledge more frequently and are more capable of knowledge creation are more efficient at research and development, as well as innovating their products more effectively [33]. From the perspective of knowledge flow, knowledge creation by an organization is based on the organization’s pursuit of creativity and innovation, which encourages its employees to create knowledge, promotes knowledge exchange between employees and across teams, and fosters new ideas and solutions to reduce redundant knowledge and increase non-redundant and heterogeneous knowledge resources that are conducive to product and process innovation [34,35]. Thus, we believe that a firm’s KCP is positively related to its technological innovation capability. On this basis, we proposed the following two hypotheses:

**Hypotheses 1a (H1a).** *A positive relationship exists between a firm’s KCP and its development of technological IC for process.*

**Hypotheses 1b (H1b).** *The effect of a firm’s KCP on technological IC for product is mediated partially by its generation of technological IC for process.*

## 2.2. KCP, Technological IC, and SCA

Numerous studies have suggested that knowledge creation is essential to businesses gaining a SCA [24,36]. As globalization continues to intensify, numerous businesses have become knowledge-intensive, and now compete with “brains” not “brawn”; against this backdrop, knowledge is deemed the most crucial factor in distinguishing a company from its competitors [37]. Therefore, businesses with greater means to acquire knowledge and a greater ability to integrate and create knowledge are more efficient at identifying and responding to rapid changes in the market and resolving the limitations of their knowledge resources to outclass rivals [36]. On this basis, knowledge creation plays a crucial role in enhancing a SCA [38]. Knowledge creation can be seen as a process through which knowledge is constantly transferred and integrated among businesses, functional departments, and individuals, or a process involving repeated conversions of tacit and explicit knowledge [21,25]. This process leads to new knowledge resources, which include new approaches to solving problems and boosting performance, new work methods, new products, new concepts, and new lines of thinking [39]. These knowledge resources enable a company to improve its efficiency, reduce its costs, or refine its products. Through this, the company improves its ability to create value for its customers, serve customer needs, and increase employee and customer satisfaction [38], thereby developing a competitive edge [40]. Thus, we believe that a firm’s KCP is positively related to its SCA. On this basis, we proposed the following hypothesis:

**Hypotheses 2 (H2).** *A positive relationship exists between a firm's KCP and its SCA.*

A SCA is the ultimate embodiment of a business's capabilities, resources, and activities, and it is a crucial criterion for whether the business allocates its resources appropriately and what outcomes it achieves accordingly. Researchers have argued that a business that is unable to continually innovate cannot operate in an increasingly competitive market, and will consequently lose its competitive advantage [41]. Additionally, with the growing penetration of big data and the Internet, knowledge is rapidly and frequently being replaced and updated; changes and developments occur every day, and business operators should constantly formulate or refine strategies to develop products or services and acquire and maintain a competitive edge [38]. From the perspective of business operation, innovating technologically—particularly through process innovation to introduce and implement “lean production” and “total quality management”—can improve production and operating efficiencies and substantially reduce costs [42]. From the perspective of target markets, technological innovation allows a business to satisfy not only customer needs for its existing products and services, but also new customer needs. Moreover, businesses that are highly capable of technological innovation are more likely to push beyond the boundaries of their capabilities and markets to identify new markets and capture the opportunities that they afford [40]. From the perspective of business models, such businesses tend to enter unfamiliar domains to create and commercialize products; the services that they postulate are groundbreaking, and the businesses pilot and promote them in existing markets [43]. Reducing costs, exploring opportunities in new markets, and providing new products or services are all outcomes of SCAs. Thus, we believe that a firm's technological innovation capability is positively related to SCA. On this basis, we proposed the following two hypotheses:

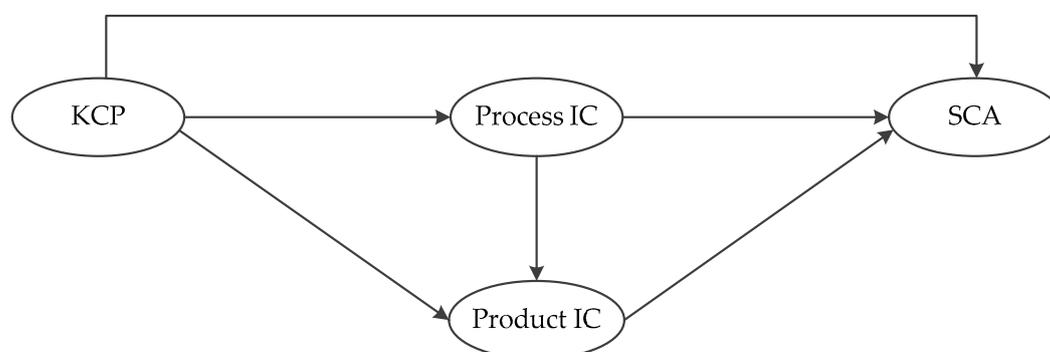
**Hypotheses 3a (H3a).** *A positive relationship exists between technological IC for process and SCA.*

**Hypotheses 3b (H3b).** *A positive relationship exists between technological IC for product and SCA.*

Process innovation was demonstrated to exert a significant direct influence on product innovation [27]. Improving process innovation capability, particularly through the innovation and optimization of the product development process, enables a company to expedite its product research and development, reduce its research and development (R&D) costs, and enhance its capability to innovate products. For example, the efficiency and quality of product innovation can be further improved by implementing product development in an integrated rather than stage-gate manner. Thus, we believe that process innovation capability is positively related to product innovation capability. On this basis, we proposed the following hypothesis:

**Hypotheses 3c (H3c).** *The effect of technological IC for process on SCA is mediated partially by the development of technological IC for product.*

The conceptual model of this research is shown in Figure 1.



**Figure 1.** Conceptual model.

### 3. Research Methods

#### 3.1. Data Collection and the Sample

To verify the hypotheses, we applied a questionnaire survey to collect data. Since the technological innovations are actually deployed in manufacturing industries, manufacturing firms in China were chosen as the research setting. China is a vast country that encompasses a wide range of regions. Different regions have different cultures, government policies, and locational conditions. In order to reduce the influences of these situational factors on the research results, we strategically selected a typical manufacturing region representing the new economic development stage in China, which is the Pearl River Delta (in southern China).

The survey was carried out between 1 July and 30 November 2016. The research participants were employees in firms in the industries of communication and computer-related equipment, electrical machinery and equipment, machinery and engineering, instruments and related products, metal products, and so on. The data collection procedure included three phases. Firstly, we developed the original English questionnaire based on previous studies, and translated it into Chinese using collaborative and iterative translation. Three management scholars with rich research experience in the knowledge and innovation management research field translated the questionnaire into Chinese. Then, we implemented two preliminary assessments to refine the item wording of the Chinese questionnaire. Three manufacturing managers and three professors reviewed the pre-questionnaire, and resolved any unfamiliar or unclear wording to improve clarity and identify. Next, we conducted a pre-test in six manufacturing firms. Based on the feedback, we detected any possible misunderstandings caused by the translation and further modified the questionnaire to make sure that the questionnaire was understandable and relevant to practices in China.

Secondly, we selected 1000 firms randomly from a list of manufacturing firms provided by the science and technology service departments of local government as our sampling frame. Following the suggestion of Frohlich [44], selected firms were contacted in advance to identify the key respondents. In order to ensure the reliability of the data regarding firms' knowledge creation processes, technological innovation capabilities, and sustainable competitive advantage, one respondent who was familiar with these activities (e.g., the top management team member, the manager of a manufacturing or R&D department, or a leader of process and product research projects) was chosen as the key respondent.

Thirdly, email or online surveys were sent out to the respondents with a cover letter that briefly introduced the objective, outlined the study, and ensured confidentiality. To encourage participation, we also offered a summary report of the study's conclusions to each respondent. In total, 343 questionnaires were collected. After deleting the responses with missing data, we received 312 valid questionnaires, yielding an effective response rate of 31.2%. The detailed characteristics of sampled firms are shown in Table 1, indicating a wide variety of sizes and industries.

We conducted several multivariate analysis of variance (MANOVA) tests to investigate the potential non-response bias [45]. An analysis of differences between early and late responses for all of the variables indicated no statistical differences, suggesting that non-response bias was not a major concern in our study.

Common method variance (CMV) was a concern in this study, as each questionnaire was finished by a single respondent [46]. We tried to reduce the potential influence of CMV by carefully selecting scale items and separating them within the fairly lengthy questionnaire. Then, two diagnostic tests were conducted to further evaluate the possibility of CMV. First, Harman's single-factor test was conducted [46]. The results revealed that no single factor emerged, and the first factor only accounted for 24.83% of the total 76.6% explained variance, indicating that CMV was not a serious concern. Secondly, we conducted confirmatory factor analysis (CFA) on Harman's single-factor model [47]. The model's fit indices of  $\chi^2/df = 8.483$ , CFI = 0.456, GFI = 0.412, TLI = 0.425, IFI = 0.458 and RMSEA = 0.155 were unacceptable, as they were considerably worse than those of the measurement

model. This suggested that the single-factor model was not acceptable, further indicating that CMV was not a serious issue.

**Table 1.** Profile of sampled firms.

Characteristics of Firms	Frequency	Percentage (%)
<b>Industry</b>		
Communication and computer-related equipment	62	19.87
Electrical machinery and equipment	56	17.95
Machinery and engineering	50	16.03
Instruments and related products	45	14.42
Metal products	48	15.38
Others	51	16.35
<b>Firm age</b>		
1–5 years	66	21.15
6–10 years	69	22.12
11–15 years	115	36.86
>15 years	62	19.87
<b>Number of employees</b>		
Large size (>1000)	101	32.37
Medium size (300–1000)	145	46.48
Small size (<300)	66	21.15
<b>Annual sales (million RMB)</b>		
Large size (>400)	116	37.18
Medium size (20–400)	142	45.51
Small size (<20)	54	17.31
<b>Ownership</b>		
State-owned	97	31.09
Private-owned	180	57.69
Foreign-owned	35	11.22

Note:  $n = 312$ ; we defined large, medium, and small sizes according to the standards issued by China's Ministry of Industry and Information Technology.

### 3.2. Variables and Measures

The questionnaire in this study consisted of four construct measurements: knowledge creation process, process innovation capabilities, product innovation capabilities, and sustainable competitive advantage. All of the measures were adapted from existing scales found in previous studies. The survey was a “tick the box” survey, and all of the items were measured using a seven-point Likert scale that ranged from “strongly disagree” (1) to “strongly agree” (7). The measurement items of all of the constructs are presented in Appendix A Table A1.

#### 3.2.1. Knowledge Creation Process

The knowledge creation process has been conceptualized as a multidimensional construct in prior studies [21,25,48]. Consistent with these previous research studies, we measured the knowledge creation process in four dimensions: socialization, externalization, combination, and internalization. These four dimensions have four, five, four, and three items respectively, and were measured using scales adapted from previous work [48]. The socialization process converts individuals' tacit knowledge into new tacit knowledge through shared experiences and joint activities [21] such as cooperative projects across directorates, employee rotation across areas, etc. The externalization process articulates the tacit knowledge into comprehensible forms that are more understandable to others [25] through adopting various tools such a problem-solving system, collaboration learning tools, etc. The combination process converts explicit knowledge collected from inside or outside the organization into more complex and systematic explicit knowledge [24] through using web pages, databases, etc. The internalization process transfers explicit knowledge into tacit knowledge [48] through on-the-job training, learning by doing, and learning by observation.

### 3.2.2. Technological Innovation Capabilities

According to previous literature [26,49], “technological innovation capabilities” have also been conceptualized as a multidimensional construct, which includes two dimensions: process innovation capability and product innovation capability. Process innovation capability is defined as a firm’s ability to develop new or significantly changed productive and technological processes. The measurement scale used in prior work [27] consisted of 11 reflective items, which assessed the extent to which process innovation capability constitutes a particular strength for the firm in comparison with its main competitors. Product innovation capability is defined as a firm’s ability to develop new or significantly improved products [26,49,50]. According to prior work [27], the measurement scale was made up by five reflective items, which assessed the extent to which product innovation capability constitutes a particular strength for the firm in comparison with its main competitors.

### 3.2.3. Sustainable Competitive Advantage

Wiggins and Ruefli [51] defined sustainable competitive advantage as a firm’s capability to achieve a series of temporary advantages over time. The measurement of sustainable competitive advantage contained six items [52], which assessed respondents’ perceptions of the extent to which their firm performed competitively in various fields (i.e., R&D, managerial capability, profitability, etc.) in comparison with its main competitors.

### 3.2.4. Control Variables

Previous studies have suggested that a firm’s innovation and competitive advantage may be influenced by firm age, firm size, annual sales, ownership, and environmental uncertainty [27,53]. Accordingly, we included these control variables in the study. Firm age was measured using a four-point Likert scale according to the time since the firm was established. Firm size was measured using a three-point Likert scale according to the firm’s number of employees. Annual sales were measured using a three-point Likert scale according to the firm’s total revenue last year. Ownership was operationalized as three dummy variables, with state-owned as the baseline. Environmental uncertainty was measured by a three-item scale used in prior work [54].

## 3.3. Reliability and Validity

The reliability of the multi-item scale for each dimension was assessed using Cronbach’s  $\alpha$  coefficient and composite reliability (CR). Table 2 showed each construct’s Cronbach’s  $\alpha$  and CR values. The Cronbach’s  $\alpha$  values of all of the constructs ranged from 0.833 to 0.957, exceeding the recommended minimum standard of 0.70 [55]. All of the CR values were larger than 0.85, which is greater than the minimum acceptable value of 0.7. So, the reliability of the measurement in this study is acceptable.

Rigorous processes were employed to evaluate the validity of this study. First, in order to ensure the content validity, we carefully extracted scales from existing constructs based on an extensive search of the literature in our study. Moreover, we conducted several iterative reviews of the questionnaire by executives and academics to clarify the item wording. Content validity was such established.

Secondly, confirmatory factor analysis (CFA) was executed to assess the convergent validity [56]. The model fit indices were as follows:  $\chi^2 = 730.689$ , degree of freedom (df) = 646,  $p < 0.05$ ;  $\chi^2 / df = 1.131$ ; comparative fit index (CFI) = 0.990; Tucker–Lewis index (TLI) = 0.989; incremental fit index (IFI) = 0.990; root mean square error of approximation (RMSEA) = 0.021. All of the indices were above the minimum acceptable values, and all of the factor loadings were higher than 0.70 and significant at the  $p < 0.001$  level (see Table 2), indicating strong convergent validity [57]. In addition, the average variance extracted (AVE) values of all of the constructs exceeded the minimum threshold of 0.50 (see Table 2), as advocated by Fornell and Larcker [55], which supports the convergent validity of the measures.

**Table 2.** Standardized item loadings, Cronbach's  $\alpha$ , composite reliability (CR) and average variance extracted (AVE) values.

Constructs	Items	$\lambda$	Cronbach's $\alpha$	CR	AVE
Socialization (SOC)	SOC1	0.821	0.900	0.902	0.697
	SOC2	0.837 ***			
	SOC3	0.870 ***			
	SOC4	0.809 ***			
Externalization (EXT)	EXT1	0.837	0.912	0.912	0.676
	EXT2	0.855 ***			
	EXT3	0.782 ***			
	EXT4	0.818 ***			
	EXT5	0.818 ***			
Combination (COM)	COM1	0.770	0.855	0.856	0.598
	COM2	0.715 ***			
	COM3	0.812 ***			
	COM4	0.793 ***			
Internalization (INT)	INT1	0.851	0.833	0.835	0.629
	INT2	0.706 ***			
	INT3	0.815 ***			
Process innovation capability (Process IC)	Process IC1	0.873	0.957	0.958	0.673
	Process IC2	0.846 ***			
	Process IC3	0.769 ***			
	Process IC4	0.846 ***			
	Process IC5	0.790 ***			
	Process IC6	0.811 ***			
	Process IC7	0.801 ***			
	Process IC8	0.809 ***			
	Process IC9	0.847 ***			
	Process IC10	0.813 ***			
	Process IC11	0.811 ***			
Product innovation capability (Product IC)	Product IC1	0.844	0.930	0.931	0.729
	Product IC2	0.868 ***			
	Product IC3	0.864 ***			
	Product IC4	0.835 ***			
	Product IC5	0.857 ***			
Sustainable competitive advantage (SCA)	SCA1	0.837	0.934	0.934	0.703
	SCA2	0.801 ***			
	SCA3	0.823 ***			
	SCA4	0.835 ***			
	SCA5	0.856 ***			
	SCA6	0.877 ***			

Note: \*\*\*  $p < 0.001$ .

In order to assess the discriminant validity, we calculated each construct's square root of AVE and compared them with correlations between pairs of constructs [55]. As shown in Table 3, the results indicated that the square root of each construct's AVE value was higher than its correlation with any other construct. Therefore, the discriminant validity was established in this study. Based on the above results, the reliability and validity of the measurements in this study are acceptable.

**Table 3.** Discriminant validity test.

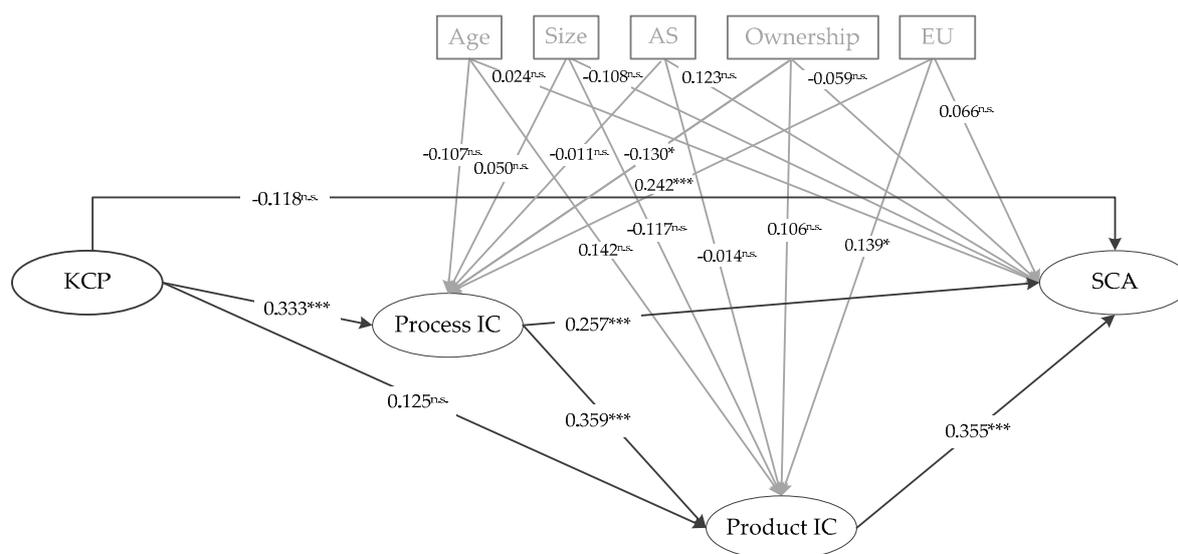
Variables	Mean	SD	SOC	EXT	COM	INT	PCIC	PDIC	SCA
SOC	4.768	1.286	<b>0.835</b>						
EXT	4.747	1.257	0.193	<b>0.822</b>					
COM	4.660	1.163	0.118	0.116	<b>0.773</b>				
INT	4.736	1.350	0.239	0.104	0.122	<b>0.793</b>			
PCIC	4.618	1.147	0.094	0.046	0.226	0.228	<b>0.820</b>		
PDIC	4.391	1.380	0.095	0.005	0.176	0.135	0.404	<b>0.854</b>	
SCA	4.246	1.132	0.012	−0.028	0.170	0.025	0.376	0.420	<b>0.838</b>

Note: PCIC: process IC, PDIC: product IC, SD: standard deviation, bold numbers on the diagonal line represent the square root of AVE.

### 4. Results

We employed structural equation modeling (SEM), using AMOS 18.0, to test the hypotheses. A set of fit indices was used to examine the structural model, which supported a good model fit ( $\chi^2 = 491.970$ ,  $df = 404$ ,  $p < 0.01$ ;  $\chi^2/df = 1.218$ ; CFI = 0.986; GFI (goodness-of-fit index) = 0.909; TLI = 0.984; IFI = 0.986; RMSEA = 0.026). Table 4 presents the results of the SEM mediation analysis. We also demonstrate the results of the full model in Figure 2. Of the six hypotheses, only five hypotheses have been supported by the empirical data. Specifically, as can be observed in Table 4 and Figure 1, the KCP has a significant effect on process IC ( $\beta = 0.333$ ,  $p < 0.001$ ), and H1a is strongly supported. Also, process IC has a significant effect on product IC ( $\beta = 0.359$ ,  $p < 0.001$ ). However, the direct effect of KCP on product IC is not significant ( $\beta = 0.125$ ,  $p > 0.05$ ). These results confirm H1b, which posits an indirect effect of KCP on product IC through process IC.

With regard to SCA, the KCP does not have a significant effect on SCA ( $\beta = -0.118$ ,  $p > 0.05$ ), indicating that H2 is not supported. Thus, we find that KCP cannot influence SCA directly. Process IC has a significant effect on SCA ( $\beta = 0.257$ ,  $p < 0.001$ ), which gives support to H3a. Product IC also has a significant effect on SCA ( $\beta = 0.355$ ,  $p < 0.001$ ), supporting H3b. Considering the significant effect of process IC on product IC, therefore, as stated in H3c, the effect of process IC on SCA is mediated partially by the development of product IC. This means that process IC positively influences SCA directly, as well as positively influences it indirectly through Product IC. Based on the above results, we can conclude that KCPs can only foster SCA indirectly through technological innovation capabilities.



**Figure 2.** The results of the full model. Note: \*  $p < 0.05$ , \*\*\*  $p < 0.001$ , <sup>n.s.</sup> non-significant, AS: annual sale, EU: environment uncertainty, KCP: knowledge creation process.

**Table 4.** Structural equation model results.

Structural Path	Proposed Effect	Path Coefficient	Results
Direct effects			
KCP→Process IC	+	0.333 ***	H1a supported
KCP→Product IC		0.125 <sup>n.s.</sup>	
Process IC→Product IC		0.359 ***	
KCP→SCA	+	-0.118 <sup>n.s.</sup>	H2 not supported
Process IC→SCA	+	0.257 ***	H3a supported
Product IC→SCA	+	0.355 ***	H3b supported
Indirect effects			
KCP→Process IC→Product IC	+	0.120	H1b supported
Process IC→Product IC→SCA	+	0.127	H3c supported

Table 4. Cont.

Structural Path	Proposed Effect	Path Coefficient	Results
Non-hypothesized (control variables)			
Age→Process IC		−0.107 <sup>n.s.</sup>	
Size→Process IC		0.050 <sup>n.s.</sup>	
Annual sale→Process IC		−0.011 <sup>n.s.</sup>	
Ownership→Process IC		−0.130 <sup>n.s.</sup>	
Uncertainty→Process IC		0.242 <sup>***</sup>	
Age→Product IC		0.142 <sup>n.s.</sup>	
Size→Product IC		−0.117 <sup>n.s.</sup>	
Annual sale→Product IC		−0.014 <sup>n.s.</sup>	
Ownership→Product IC		0.106 <sup>n.s.</sup>	
Uncertainty→Product IC		0.139 <sup>*</sup>	
Age→SCA		0.024 <sup>n.s.</sup>	
Size→SCA		−0.108 <sup>n.s.</sup>	
Annual sale→SCA		0.123 <sup>n.s.</sup>	
Ownership→SCA		−0.059 <sup>n.s.</sup>	
Environment uncertainty→SCA		0.066 <sup>n.s.</sup>	

Note: \*  $p < 0.05$ , \*\*\*  $p < 0.001$ , <sup>n.s.</sup> non-significant, + the path coefficient is positive.

## 5. Conclusions

### 5.1. Discussion

This study combined the KBV with a technological innovation perspective and experimentally confirmed that technological innovation capability mediated the influence of the KCP on SCA. On the basis of the OECD definition of technological innovation, technological innovation was divided into the dimensions of process and product innovation. This study discovered that technological innovation capability mediated the role of the KCP in the development of SCA. These findings provide valuable insights for manufacturing firms to foster their SCA through implementing KCPs and strengthening their technical innovation abilities.

Considering the direct effect of the KCP on SCA, our findings indicated that KCPs do not have a direct positively significant effect on SCA. This conclusion was inconsistent with our hypotheses, probably because, from the KBV, knowledge creation is the core task of a business and the knowledge created by members of a business through social interaction (particularly tacit knowledge, which is difficult to articulate, imitate, and disseminate) is a crucial source of SCA [7,21,58]. However, knowledge creation does not necessarily lead to stronger SCA. One immediate outcome of exploiting that advantage is that a business can respond to market changes effectively and develop products or services continually to satisfy customer needs, dominate market shares, and achieve a greater operational performance than its competitors [9,59]. This allows a business to acquire business value. For businesses, knowledge creation lays the groundwork for new technologies, new products, or new services, which help the firms achieve a positional advantage in obtaining SCA [60]. However, this does not mean that all of the companies can achieve a SCA successfully through creating new knowledge. Many businesses that create knowledge do not achieve successful commercialization; therefore, this study empirically verified that KCPs do not directly strengthen SCA. Two examples are cited to illustrate this point. Kodak, despite creating knowledge about digital photography and inventing digital photography techniques, did not benefit from its brainchild. Although Apple created knowledge about personal computers and inaugurated the world's first, it was IBM that first achieved commercial success in this domain.

The analysis of the relationships among the KCP, technological innovation capability, and SCA yielded the following findings. The KCP favors the development of process innovation capability, but doesn't directly positively affect product innovation capability. This result indicates that the relationship between KCP and product innovation capability is completely mediated by process innovation capability. In addition, the positive impact of KCP on SCA is not significant, but both

process and product IC had a significant direct effect on SCA, as did process innovation capability on product innovation capability. These findings highlight that simply implementing a KCP is not sufficient to favor SCA; it would be necessary to put it through process and product innovation capability. Accordingly, the KCP encourages a business to improve its technological innovation capability, thereby gaining a SCA. This conclusion, which is derived from an empirical verification of the mechanism through which the KCP influences the SCA, contrasts with quantitative investigations on what underlies the relationship between the KCP and SCA [4,5,7].

Numerous studies have suggested that as global competition continues to intensify, the more knowledge businesses create, the faster they can identify trends in technological and market development and act accordingly to secure advantageous positions in the market [36,61]. Additionally, businesses that are more capable of knowledge creation typically wield stronger SCAs; therefore, academic research has often found knowledge creation and SCA to be positively related. However, their statistically proven correlation does not accurately explain how knowledge creation, which leads to new knowledge resources (such as product concepts, manners of work, and lines of thinking), translates into the SCA. This study argued that only when process and product IC are improved do these knowledge resources influence SCAs. This conclusion contributes theoretically to the understanding of how businesses acquire SCAs through knowledge creation.

### *5.2. Managerial Implications*

The findings of this study also provide crucial implications for manufacturing firms to carry out KCPs to acquire a SCA more effectively. First, managers should devote themselves to transforming their firms into learning organizations, which can drive firms to become more efficient at acquiring, integrating, and creating knowledge, thereby producing knowledge continually. A learning organization is an organization that allows its members to adopt effective learning mechanisms to create knowledge and values. Enhancing organizational learning is instrumental in building a learning organization. Managers can advance organizational learning through establishing a learning platform, fostering a learning culture, implementing an incentive mechanism, encouraging employees to acquire knowledge outside the organization, etc. In addition, managers have to promote dynamics and spirals of knowledge creation by taking a leading role in managing the SECI process. Managers can nurture an enabling environment that encourages employees to communicate with each other (to facilitate the exchange of tacit and explicit knowledge within the organization) and provide various types of trainings on learning methods (such as acquisitive learning, experiential learning, and learning by doing) to promote the acquisition, integration, and creation of knowledge by employees and improve the organization's capability in creating knowledge.

Second, the results of this paper indicate that the KCP does not directly strengthen SCA, but can strengthen SCA through the mediation of technological innovation capability. Therefore, the most important practical implication of this paper is that managers should be aware of the importance of the KCP in the link between technological IC and SCA. Our findings indicate that merely concentrating on the KCP may not be sufficient, despite the commonly held view that knowledge is the most important strategic asset that enables firms to develop a SCA [9]. Technological IC seems more important in helping firms obtain a SCA. This is consistent with the research that argues that firms stand to benefit from investing in their technological innovation capabilities for products and processes that generate the most valuable, distinctive, and difficult to imitate strategic assets that allow the firms to achieve superior performance [27]. Thus, while focusing on locating, capturing, transferring, sharing existing knowledge, and creating new knowledge, managers should also concentrate on providing spaces and opportunities for individuals or teams to engage in improving technological IC at the same time.

### *5.3. Limitations and Future Research*

This study has two limitations. First, a convenience sample of manufacturing firms in the Pearl River Delta region of China was used, which limited the generalizability of the findings. China is a

vast country in which the development of businesses is subject to local political, cultural, and resource contexts. Future studies should investigate larger samples to further generalize their findings. Second, this study employed cross-sectional data to analyze the influence of knowledge creation on technological innovation capability and SCA, despite the relationship being a dynamic process. Third, concrete outcomes are difficult to observe within a short period of time. Thus, longitudinal research should be conducted in order to investigate knowledge creation and its results in businesses; this would improve the understanding of how knowledge creation contributes to technological innovation capability.

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**Author Contributions:** Chuanpeng Yu and Yenchun Jim Wu conceived and designed the experiments; Chunpei Lin performed the experiments; Chuanpeng Yu and Chunpei Lin analyzed the data; Zhengang Zhang contributed reagents/materials/analysis tools; Chuanpeng Yu wrote the paper.

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## Appendix A

**Table A1.** Survey instrument (with factor loadings).

Item	Loading
Socialization ( $\alpha = 0.900$ )	
SOC1: My firm usually adopts cooperative projects across directorates	0.821
SOC2: My firm usually uses apprentices and mentors to transfer knowledge	0.837
SOC3: My firm usually adopts brainstorming retreats or camps	0.870
SOC4: My firm usually adopts employee rotation across areas	0.809
Externalization ( $\alpha = 0.912$ )	
EXT1: My firm usually adopts a problem-solving system based on a technology like case-based reasoning	0.837
EXT2: My firm usually adopts groupware and other learn collaboration tools	0.855
EXT3: My firm usually adopts pointers to expertise	0.782
EXT4: My firm usually adopts modeling based on analogies and metaphors	0.818
EXT5: My firm usually captures and transfers experts' knowledge	0.818
Combination ( $\alpha = 0.855$ )	
COM1: My firm usually adopts web-based access to data	0.770
COM2: My firm usually uses web pages	0.715
COM3: My firm usually uses databases	0.812
COM4: My firm usually adopts repositories of information, best practices, and lessons learned	0.793
Internalization ( $\alpha = 0.833$ )	
INT1: My firm usually adopts on-the-job training	0.851
INT2: My firm usually adopts learning by doing	0.706
INT3: My firm usually adopts learning by observation	0.815
Process innovation capability ( $\alpha = 0.957$ )	
Process IC1: My firm is able to create and manage a portfolio of interrelated technologies	0.873
Process IC2: My firm is able to master and absorb the basic and key technologies of business	0.846
Process IC3: My firm continually develops programs to reduce production costs	0.769
Process IC4: My firm has valuable knowledge for innovating manufacturing and technological processes	0.846
Process IC5: My firm has valuable knowledge on the best processes and systems for work organization	0.790
Process IC6: My firm organizes its production efficiently	0.811
Process IC7: My firm assigns resources to the production department efficiently	0.801
Process IC8: My firm is able to maintain a low level of stock without impairing service	0.809
Process IC9: My firm is able to offer environmentally friendly processes	0.847
Process IC10: My firm manages production organization efficiently	0.813
Process IC11: My firm is able to integrate production management activities	0.811
Product innovation capability ( $\alpha = 0.930$ )	
Product IC1: My firm is able to replace obsolete products	0.844
Product IC2: My firm is able to extend the range of products	0.868
Product IC3: My firm is able to develop environmentally friendly products	0.864
Product IC4: My firm is able to improve product design	0.835
Product IC5: My firm is able to reduce the time to develop a new product until its launch in the market	0.857

Table A1. Cont.

Item	Loading
Sustainable competitive advantage ( $\alpha = 0.934$ )	
SCA1: The quality of the products or services that my firm offers is better than that of the competitor's products or services	0.837
SCA2: My firm is more capable of R&D than the competitors	0.801
SCA3: My firm has better managerial capability than the competitors	0.823
SCA4: My firm's profitability is better	0.835
SCA5: The corporate image of my firm is better than that of the competitors	0.856
SCA6: The competitors are difficult to take the place of my firm's competitive advantage	0.877

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