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Original Paper

Sustainable Innovation Model for Science and Technology-Based SMEs: Evidence from China

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Abstract

This study proposes a sustainable innovation model for science and technology-based small and medium enterprises (SMEs) using grounded theory in the Chinese context. Five SMEs, referred to as 'science and technology small giants', were chosen as sampling cases to gather information for the grounding procedure to provide insights into successful science and technology-based SMEs. The model illustrates possible development paths for science and technology-based SMEs seeking to progress towards sustainable innovation and is potentially generalisable to SMEs in other industries, offering empirical insights to corresponding enterprises that seek innovative enhancement especially in developing countries. The results suggest that the innovation team, innovation principles, and an innovation base are indispensable elements to consider. Building teams with innovative human resources under the guidance of a clear system of principles can largely maximise the efficiency of creative talent and thus advance continuous innovation outcomes. An innovation base is also indispensable to reduce primary defects in initial investment, networking, supply chains, and market reputation.

Keywords

sustainable innovation, small-medium enterprises, innovation management

1. Introduction

As the world enters a new era of the knowledge economy, governments are increasing the pace of scientific research and exploration. Under these circumstances, sustainable innovation represents the core competitiveness of countries. According to Samonis (2004), economic prosperity in Europe is determined by the frequency of innovation, especially sustainable innovation. Rahman et al. (2015) stated that evaluating innovation is important for the overall innovation capability and sustainability of a firm because it is a dynamic process. Kar et al. (2019) found that sustainable innovation is crucial when considering long-term solutions in terms of planning, processing, and execution. Moreover, according to Xu et al. (2020), as sustainable innovation has become a global discussion, sustainable technological innovation is necessary to alleviate the problem of excess production capacity in the Chinese economy.

Most relevant studies have focused on discovering criteria for assessing regional sustainable innovation or indicators for measuring it within enterprises. However, science and technology-based corporations are rarely discussed, and the perspectives from China are insufficient. Science and technology-based small and medium enterprises (SMEs) are important drivers of economic development in China (Chen et al., 2009). Science and technology-based SMEs are different from other SMEs because they are more knowledge-intensive and have unique innovation paths and growth models (Chen & Ma, 2012). According to Kim and Ha (2010), the knowledge-intensive industry is perceived as a critical instrument for firms to gain competitive advantage, thus, the overall development of these SMEs are important to innovation development and regional economic growth. Moreover, due to technological iteration in this field, maintaining sustainable innovation is essential. Unlike large enterprises, SMEs face greater risks in cash flow, interpersonal connections, and marketing plans (Muzzi & Albertini, 2014; Caballero-Morales, 2021), and determining the dynamics of sustainable innovation in science and technology-based SMEs is important in China, where competition and involution is intense in almost every field. Moreover, examining such dynamics could possibly offer valuable experience for SMEs in other industries that seek innovation-oriented development, especially in developing countries.

With respect to studies that define sustainable innovation in enterprises (Boons & Lüdeke-Freund, 2013; Hautamäki & Oksanen, 2015; Little, 2006) and their frameworks in SMEs (Cao et al., 2012; Cao et al., 2013; Dubois & Roto, 2012; Muzzi & Albertini, 2014; Strese et al., 2016), this study selects five successful science and technology-based SMEs that have attained sustainable innovation recognition as study cases to gather both public and non-public information via various information platforms and personal interviews with management. Using the gathered and coded information, this study proposes a sustainable innovation model based on the grounded theory. As the selected case studies are representative of science and technology-based SMEs in China, this study aims to infer from their experience and knowledge to offer development recommendations for similar enterprises in China, as well as add insights on the organisational development path of science and technology SMEs to the current literature.

2. Literature Review

2.1 Sustainable Innovation in Business Management

Sustainable innovation strategies are popular in management research, and developing corresponding conceptual business models enhances potential in various industries. Sustainable innovation includes multiple new concepts such as sustainable development, ecosystem thinking, continuous innovation, and innovation leadership (Hautamäki & Oksanen, 2015). Little (2006) defined ‘sustainability-driven innovation’ as the creation of new products and services driven by social and environmental sustainability issues. This creative process improves sustainability performance based on ecological, economic, and social criteria (Boons & Lüdeke-Freund, 2013), and represents the core of future business models to address pressing challenges and prevent negative outcomes (Bocken et al., 2014). Therefore, sustainability-driven business management seems to be a promising direction for enterprises seeking to enhance their competitiveness.

Discussed repeatedly, a holistic framework of sustainable innovation helps to develop functional, sustainable, and valuable business performance. York and Danes (2014) suggested that an entrepreneurial view of innovative development is necessary for small enterprises to effectively allocate their resources and, hence, progress their creative development and create customer value. Emilsson et al. (2020) expressed that, to pursue the long-term sustainable innovation of digital technologies, companies should have a strategic vision, unique and sustainable products or services, positive attitude towards innovations, and be receptive to collaboration. Therefore, a solid framework of sustainable innovation helps enterprises achieve an optimal balance of competing and complementary stakeholder interests, proliferate innovation production consistently, and most importantly, boost continuous economic growth and value creation in business (Bommel et al., 2020; Reinhardt et al., 2020; Yip & Bocken, 2018).

2.2 Sustainable Innovation in SMEs

Science and technology-based SMEs are playing an increasingly important role in global economic development. These SMEs are the most likely to survive among all new enterprises in the highly competitive sustainable innovation field (Shearman & Barrell, 1988). It is widely acknowledged that innovation promotes the sustainable development of SMEs and keeps them competitive in the market, because achieving sustainable development is inextricably linked to technological innovation, and small business management has an inherent potential for technological innovation development (Linton & Solomon, 2017; Shrivastava et al., 2016; Xie et al., 2010). Although small companies face difficulties when choosing an innovation development direction, most SMEs are positively adapting to the current knowledge economy by changing their offerings using new technology (Emilsson et al., 2020; Linton & Solomon, 2017). Thus, researching the development path and evaluation index of the sustainable innovation capability of science and technology-based SMEs could be valuable for a country’s overall innovation development.

Previous studies have identified multiple factors that are considered influential on the sustainable innovation ability of SMEs: entrepreneurs' desire for innovation, annual research investment, annual income from innovation achievements, success rate of new products in the market, enterprise financing ability, technical expertise, customer management, tax policies, size and structure of firms, local conditions and business communities' dynamism, resource input and innovation process capability, and networking and access to knowledge bases and CEO's passion for inventing (Cao et al., 2012; Cao et al., 2013; Dubois & Roto, 2012; Muzzi & Albertini, 2014; Strese et al., 2016; Xie et al., 2010). As per recent proposals, establishing a sound development model for science and technology-based SMEs by reviewing existing innovation practices is crucial for the management and survival of these organisations (Abbas et al., 2020; Saunila, 2020). To realise continuous innovation and business development, an overarching sustainable innovation model considering the factors mentioned above is essential.

2.3 Sustainable Innovation Models in China

Studies on increasing the effectiveness of China's sustainable innovation indicate that multiple indices systems and business models of innovation ability evaluation have been developed for sustainable innovation development. For instance, Zheng (2001) considered that input capacity, production capacity, marketing ability, financial ability, innovation potential, output capacity, and environmental adaptability are necessary for comprehensive sustainable innovation. Yang and Duan (2007) proposed an evaluation index for sustainable innovation, which includes variables such as innovation input ability, innovation management ability, research and development ability, manufacturing ability, marketing ability, and entrepreneurial innovation consciousness. Similarly, Li and Zhang (2009) examined sustainable innovation in enterprises through a systematic investigation of operations and proposed a sustainable innovation model consisting of four elements: sustainable technology, system, management, and market innovation abilities. According to Wu and Zhao (2011), sustainable innovation includes technological innovation, institutional innovation, and control abilities. Zhu et al. (2011) suggested that competition fairness, access to financing, laws and regulation, tax burdens, and supporting systems are identified as key factors that support the sustainable innovation development of SMEs in China. Cao et al. (2020) proved that innovative resources positively influence responsible innovation and that such resources are partially mediated by promotion focus and adaptive governance. Their evaluation systems included multiple perspectives and abundant empirical research.

However, these studies are rather broad in scope; few studies have discussed sustainable innovation models for science and technology-based SMEs in China, leaving a gap for such a model. The majority of companies in China today are SMEs but achieving sustainable innovation status is difficult due to limited investment and resources, vulnerable supply chains, delicate customer relationships, restrained expansion, and insufficient experience (Caballero-Morales, 2021; Chen et al., 2017). Therefore, determining appropriate components in a sustainable innovation model for SMEs is important. Further, as science and technology-based SMEs are the micro foundation of the national innovation system (Xie, 2010) and important in promoting the high-quality development of China's economy (Shang, 2021), creating a sustainable innovation model for innovation components to more effectively alter China's development path from production to innovation is important. Additionally, science and technology-based SMEs should use a specially formulated model because they differ from non-science and technology-based SMEs in terms of technological innovation and growth (Chen & Ma, 2012). In the post-COVID-19 pandemic period, a reliable, sustainable innovation model for science and technology-based SMEs based on previous successful experiences could offer guidance to new SMEs and those facing development challenges, supporting their continuity and the overall economy.

3. Method

Although quantitative design using surveys dominates the field of SME innovation-related studies, several studies have used qualitative design to deepen research understanding. Co-word analysis by classification algorithm has been used in qualitative research in this field to generate themes or measure density of factors (Callon et al., 1991; de Miguel Molina et al., 2019; Saunila, 2020; Shrivastava et al., 2016), but major drawbacks hindered its use in this study. First, co-word analysis is mostly used in literature analysis than in case studies, which involve oral communication and difficulties in classifying the standardised and differentiated, thereby affecting results (Leydestorff, 2006; White & Griffith, 1981). Second, the adjustment and weighting of keywords may not be scientific, and are heavily controlled by dictionary term specification and manual intervention (Kipp, 2006; Li, 2017).

Therefore, majority of qualitative research in the field of innovation management have used the grounded theory (Glaser & Strauss, 1967; Jia & Tan, 2010) because of three reasons: first, it consists of systematic inductive guidelines for collecting and analysing data to generate abstract theoretical frameworks of specific situations that explain the data while grounding these frameworks in the data (Corbin & Strauss, 2015; Creswell, 2013; Denzin & Lincoln, 2002). In this case, building a model from the data offered by the relative cases is adequate. Second, the grounded theory starts from an actual situation and summarises relevant information from the raw data to construct a model or path without being based on a prior theoretical setting (Corbin & Strauss, 2015). Therefore, using the grounded theory can characterise successful enterprises in the field, preventing the sustainable innovation model of science and technology-based SMEs from being negatively affected by previous indices or models. Third, the grounded theory is not only applicable to multi-case studies but also single case studies; hence, it is usually adopted for the case analysis of enterprises to study their development path, incubation fission process, transformation approach, and business model innovation (Abamonga, 2019). Further, as qualitative studies based on case studies are better options to investigate in-depth information (Zahoor & Al-Tabbaa, 2020), this study constructed a sustainable innovation model for science and technology-based SMEs using the information gathered by multiple case interviews and subsequently coded based on the grounded theory.

3.1 Case Selection

This study focused on science and technology-based SMEs in China to determine sustainable innovation model composition. A purposeful sampling technique was used to deliberately select cases that suit the research aims (Siggelkow, 2007) and five science and technology-based SMEs that attained the title of 'science and technology small giants' (see Table 1). This title is one of the greatest recognitions of sustainable innovation and development for such enterprises in China and is based on the following criteria—annual sales revenue of 1–2 million Yuan, over 10 percent average net profit growth rate, an asset-liability ratio below 70 percent, over 15 percent research and development personnel ratio, more than 4 invention patents related to main products, and more than 15 brands or trademarks at or above the provincial level (Ministry of Industry and Information Technology of China, 2018). Studying the continuous innovation of these companies undoubtedly inspires other enterprises.

Table 1. Five Chosen Science and Technology Small Giants

SMEs	**Initials***	**Type**	**Annual sales revenue (millions)**	**Average growth rate of net profit over 10%**	**Asset-liability ratio below 70%**	**R&D personnel ratio over 15%**	**Invention patents related to main products (≥ 4)**	**Brands or trademarks at or above the provincial level (≥ 15)**
1	ZXSK	Communication and Internet	391.25	Y	Y	Y	Y	
2	BLW	Product Development	277.35	Y	Y	Y		Y
3	HFZY	Game Development	390.66	Y	Y	Y	Y	
4	JW	Internet of Things	269.88	Y	Y	Y		Y
5	HFCN	Software Development	245.99	Y	Y	Y	Y	Y

* Respondents were promised anonymity. Y indicates that the related SME meets the criterion.

3.2 Data Collection

Based on the aforementioned evaluation criteria, sustainable innovation paths in science and technology-based SMEs were generated for five SMEs in China that are ‘small technology giants’ using an in-depth case research approach to characterise the cases and ensure appropriate selection for generating a new theory of social phenomena or extend experiences (Easton, 2010; Yin, 2013).

The data collected for grounded theory coding in this study are of two types. The first type was obtained through public channels, including the date of company listing, the company’s annual statements, interviews and reports from various media on the company’s corresponding personnel, and stock platform annual report. Robson (2011) suggested that individual viewpoints and experiences should be considered to understand research questions comprehensively. The other type was non-public information disclosed during personal interviews with the management of the case companies, including information obtained after internal data desensitisation and declassification and other relevant information. Overall, 51 management personnel were interviewed, among which 4 were executive management, 16 were middle management, 31 were general managers and administrators. All the interviewees were guaranteed anonymity and provided appropriate informed consent.

3.3 Coding and Model Building

This study adopted the programmed version of the grounded theory proposed by Corbin and Strauss (2015), which is believed to be procedural, formulaic, and most widely used (Fei, 2008). In line with the three-level coding of Corbin and Strauss (2015), this study used a three-step process to ground the analysis of the collected data: extracting concepts and core themes through open coding, initial categories and categories through axial coding, and core categories through selective coding. A popular qualitative research software, NVivo, was used to perform the grounded theoretical analysis (Liu et al., 2017; Wu, 2018). This study used the NVivo 11 Pro version (QSR International Pty Ltd. 2020), which permits a wide range of data analyses and more complex analyses.

The coding procedure looked for sustainable innovation themes in the transcripts of different contributors. This study determined whether to re-code based on the literature on sustainable innovation and the interview transcripts after three coding steps.

4. Result

The ground results were presented after numerous rounds, which included 22 initial categories (see Table 2 a1–a22), 9 categories (see Table 3 s1–s9), and 3 core categories (see Table 4 c1–c3). Part of the open coding example and concepts specification are illustrated in Appendix Tables 1 and 2. The model is hence constructed according to the grounded results (see Figure 1).

Table 2. Conceptual Connections

Core Themes	Initial Categories
b1 Flexible talents, b2 Introduction of excellent personnel, b3 R&D team building	A1 Team building
b4 Organising training, b5 Self-learning, b6 Personnel capacity improvement, b7 International exchange	A2 Personnel capacity improvement
b8 Flexible operation mechanism, b9 Entrepreneurship, b10 Humanistic concerns	A3 Entrepreneurship
b11 Overall development strategy and plan, b12 Innovation strategy and plan	A4 Innovation strategy
b13 Effective system, b14 R&D mechanism	A5 System guarantee
b15 Implementable process, b16 Process improvement	A6 Executable process
b17 Innovation consciousness, b18 Organisational culture	A7 Innovation culture
b19 Service mode innovation, b20 Business model innovation	A8 Supporting innovation
b21 Intellectual property right, b22 Patent standard, b23 Technology innovation platform, b24 IT system	A9 Foundation of innovative technology
b25 Technology loss risk, b26 Technology loss control	A10 Prevention and control of technology loss
b27 Innovation and development department, b28 Each performs its own functions	A11 Innovation organisation
b29 Strategic alliance, b30 International cooperation, b31 Resource integration	A12 Resource integration
b32 R&D Efficiency, b33 Effective communication	A13 R&D efficiency
b34 Innovation incentive, b35 Technological innovation incentive	A14 Innovation incentive
b36 Promotion, b37 Salary and treatment	A15 Company benefits
b38 Staff assessment, b39 Linkage of assessment and treatment	A16 Linkage of assessment and treatment
b40 Profitability sustainability, b41 High input	A17 R&D investment
b42 Research resources, b43 Real estate property	A18 Innovative material base

b44 New products and technologies, b45 Leading technology	A19 Leading products and technology
b46 Develop customers market, b47 Market leading, b48 Market competition	A20 Market leading
b49 Industry growth, b50 Innovation policy	A21 Innovative macro environment
b51 Customer orientation, b52 Meet customer needs	A22 Customer demand

Table 3. Axial Coding Results

Initial Categories	**Categories**
A1 Team building, A2 Personnel capacity improvement	S1 Innovative team
A3 Entrepreneurship, A4 Innovation strategy	S2 Entrepreneurship
A5 System guarantee, A6 Executable process	S3 System process
A7 Innovation culture, A8 Supporting innovation	S4 Innovative culture
A9 Foundation of innovative technology, A10 Prevention and control of technology loss	S5 Innovation technology platform
A11 Innovation organisation, A12 Resource integration, A13 R&D Efficiency	S6 Innovation organisation
A14 Innovation incentive, A15 Company benefits, A16 Linkage of assessment and treatment, A17 R&D investment, A18 Innovative material base	S7 Innovation investment
A19 Leading products and technology, A20 Market leading	S8 Leading driving forces
A21 Innovative macro environment, A22 Customer demand	S9 Innovation demand

Table 4. Selective Coding Results

Categories	**Core Categories**
S1 Innovative team S2 Entrepreneurship	C1 Innovation team
S3 System process S4 Innovative culture	C2 Innovation principles

S5 Innovation technology platform	
S6 Innovation organisation	
S7 Innovation investment	C3 Innovation base
S8 Leading driving forces	
S9 Innovation demand	

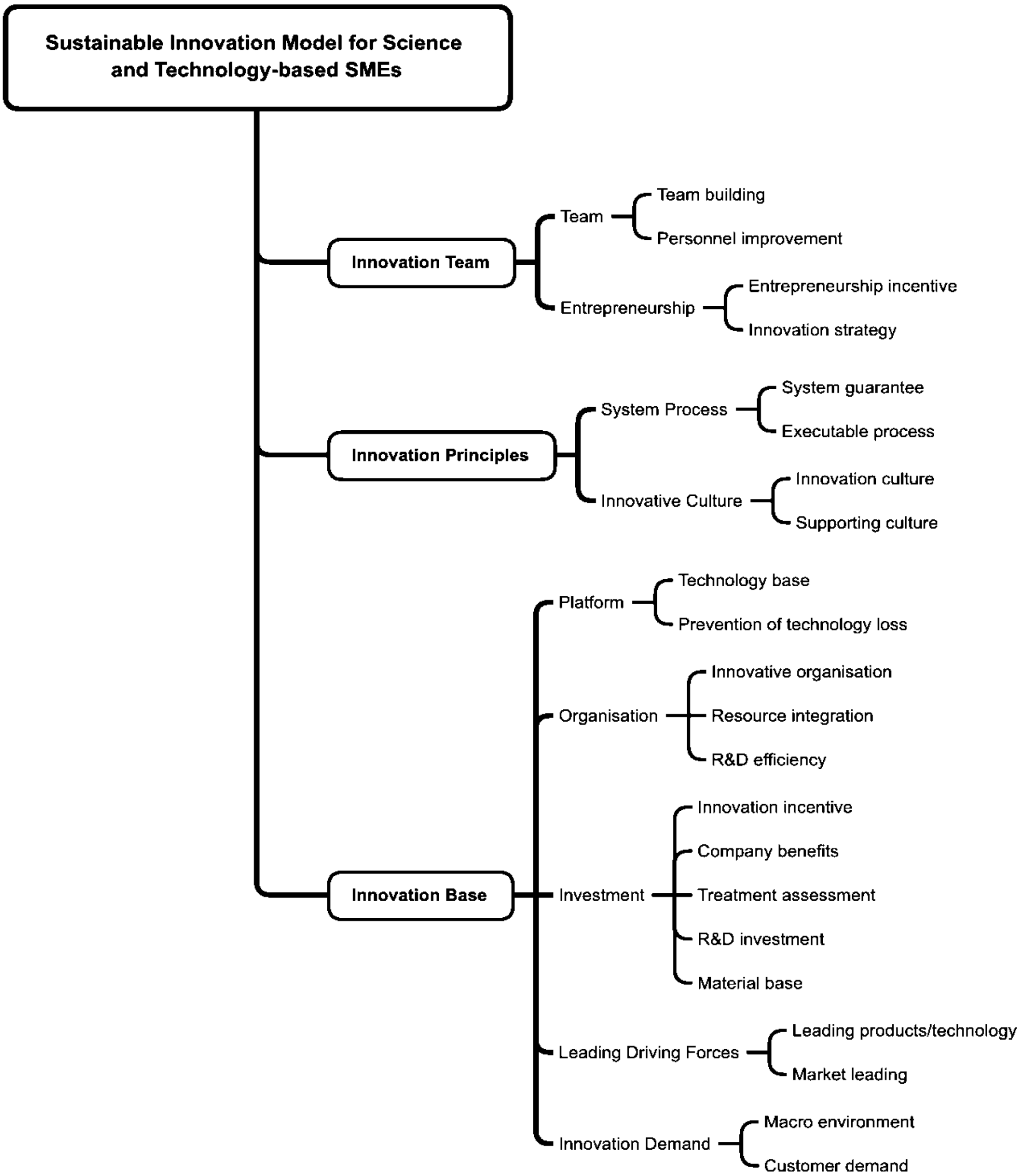

Figure 1. Sustainable Innovation Model for Science and Technology-based SMEs

5. Discussion

5.1 Findings

The model can be applied to other science and technology-based SMEs in the Chinese context, and the identified indicators should be considered by enterprises interested in pursuing sustainable development through a creative path. Furthermore, with regard to the data from both public and non-public channels, the model can be elaborated by the following directions derived from the three core categories to guide the development of such companies.

5.1.1 Innovation Team

The first is the innovation team. Florida and Davison (2001) suggested that human resources should promote sustainable innovation in organisations. Mousa and Othman (2020) also conveyed that sustainable performance in organisations requires implementing policies and practices using human resources, suggesting that human resources are the basis for continuous innovation output. The results generated from core themes of categories suggested that by accumulating flexible talents, introducing excellent personnel, and forming research and development (R&D) groups, a solid team could be built to guarantee constant innovation output.

Furthermore, technology-intensive industries need to respond to constant changes for continuous technological innovations, which requires leaders with a dominant functional experience in innovation strategy, commercialisation, and decision-making (Kim & Ha, 2010). The results of this study not only affirmed the importance of leadership but also emphasised the need for continuous personnel capacity improvement through organisational training, self-learning, and international exchange in order to foster sustainable innovation within science and technology-based SMEs. Moreover, entrepreneurs play instrumental roles in generating innovation outcomes by identifying market opportunities, nurturing organisational technological capabilities, seeking external support, establishing and modifying innovation processes, and ensuring customer satisfaction (Krishnaswamy et al., 2010).

Additionally, the results of this study emphasised the importance of entrepreneurship for innovative team building, as R&D capability alone is not sufficient to survive in the overly competitive science and technology market. Flexible operation mechanisms, entrepreneurship, and humanistic concerns are also indispensable. Finally, in order to achieve sustainable innovation, particularly in a dynamic industrial environment such as that in developing countries, innovation activities are strongly affected by strategic agenda; in this regard, organisational structure and strategy focus have a profound influence on innovation performance (Kim & Ha, 2010). The results of this study suggested that an overall development strategy focused on innovation is crucial for science and technology-based SMEs in China, and it should be seamlessly integrated into the innovation team’s entrepreneurship culture.

5.1.2 Innovation Principles

The second direction is represented by innovation principles. According to the grounded results and the details from the interviews, the innovation team should operate under certain rules. First, R&D as well as innovation and productivity share a circulative and inter-dependent relationship (Bong & Park, 2020). Second, institutional voids may create organisational tension in the form of internal barriers and motivators, resulting in sustainability paradoxes in business performance (Chiappetta Jabbour et al., 2020). Consequently, it could be deduced that employees would give full play to subjective initiatives only if all personnel follow the innovation principles and innovate continuously to the best of their abilities.

The results demonstrated that system guarantee in the form of effective R&D incentive mechanism lays the groundwork for a virtuous innovation circle for science and technology-based SMEs in China. In addition, in the small business context, innovation capability is usually an outcome of a vital creativity process and overall firm performance (Saunila, 2020). The challenge lies in the intentional process of transforming novel and useful ideas into product innovation, which requires risk-taking, as SMEs are vulnerable to potential hazards (Caballero-Morales, 2021; Castillo-Vergara & García-Pérez-de-Lema, 2020; Muzzi & Albertini, 2014). According to Behnam and Cagliano (2019), a clear orientation of internal and external resources is more necessary than research expenditure and knowledge capital growth for innovative firms.

According to the findings of this study, an executable process that is both implementable and evolving is required for science and technology-based SMEs to continuously produce innovative outcomes. Moreover, as this study was conducted in China, a developing country, the context should not be overlooked. Many developing Asian countries are regarded as science and technology innovation latecomers because their development priorities were primarily in manufacturing or agriculture, and their innovation paths typically begin with imitation, resulting in organisational management mindset challenges (Dahlman et al., 1987; Kim, 1997; Kim & Ha, 2010).

Furthermore, the results suggested that innovation consciousness and innovation organisational culture, which are fostered by recognising originality and perseverance in innovation, are essential for science and technology-based SMEs, thereby continually nurturing innovative production. Admittedly, in the process of nurturing innovation-focused SMEs from imitation to actual innovation, a well-coordinated, flexible, and decentralised organisational structure is beneficial in motivating the creativity of technical experts to produce successful innovation outcomes (Kim & Ha, 2010). Moreover, the results demonstrated that principles supporting innovation in both service and business contexts are critical throughout the operating process.

5.1.3 Innovation Base

The third direction is an innovation base. Based on the selected cases, it can be concluded that the innovation base is indispensable. Four out of the five enterprises selected in this study turned out to be subsidiaries of successful parent companies; therefore, they have access to more resources than the science and technology-based SMEs at the founding stage. As Gandia and Gardet (2017) stated, SMEs rely on resources and skills to guide their strategic choices to innovate. According to Lu et al. (2020), potential absorptive capacity and government institutional support affects innovation performance of SMEs in China. Therefore, an innovation technology platform with foundational resources, such as an excellent initial team, corresponding technological foundation, R&D experience, management philosophy, organisational structure, a leading market position obtained from the parent company, and inherited intangible assets (such as brand advantages and technology use rights from the parent company), provide new science and technology-based SMEs with a competitive advantage.

However, risks are unavoidable in the process and as Castillo-Vergara and García-Pérez-de-Lema (2020) proposed, the SME creative process involves innovating products through risk-taking. Kim and Ha (2010) also mentioned that although majority of SMEs seek to become more innovation-focused, supporting resources are scarce. In the current knowledge era, small businesses related to technology innovation, security, and reliability of technology and innovation resources require consideration (Linton & Solomon, 2017); thus, risk bearing becomes vital for science and technology-based SMEs to continue their deliberate incubation of random ideas into intentional creative outcomes. Additionally, the results suggested that having an innovation technology platform has a significant advantage in terms of preventing and controlling technology loss risk.

Furthermore, according to in Xu et al. (2008), Chinese SMEs rely on understanding and leveraging business networks for sustainable innovation development, indicating that resource integration through relationship networking is essential for Chinese SMEs. Kim and Ha (2010) suggested that linkages with external technological institutes, universities, government-funded research schools, and group firms are important. Accordingly, the results proved the aforementioned by stressing the importance of strategic alliances and organisational innovation. In addition, as the innovation return on investment from external resources is low, Chinese SMEs have relatively low incentives to increase internal R&D intensity.

It is proposed that the ideal scenario for innovation activities necessitates reliance on external investment for the initiation of innovation activities, successful commercialisation, and bearing the capacity of market and technology revolution (Kim & Ha, 2010; Mei et al., 2019). Consequently, an innovation base should include an effective innovation investment system to integrate resources and increase R&D efficiency.

Furthermore, leading driving forces in the form of initial product market and brand advantages are frequently mentioned in interviews. Endogenous interactions between technology, the market (Zhang & Pei, 2020), and technology market maturity (Xu et al., 2020) are key to improving science and technology-based SMEs’ sustainable innovation resilience, especially in China. An inherited product and brand reputation can help such SMEs be more efficient than those that start from scratch, emphasising the importance of leading products and technology in the market.

For innovation demand, the results indicated that the innovation process is strongly affected by a built-in mechanism for continuous customer interactions because they cause changes in technological and product needs, stimulating periodic new product development and continuous innovative outcomes, which serve as performance indicators of sustainable innovation in SMEs (Krishnaswamy et al., 2010). In the results of this study, the importance of reciprocal customer-enterprise effect is represented by customer demand. The innovative macro environment is also perceived as influential towards the overall innovation demand because it undoubtedly affects industry growth and innovation policy, which ultimately leads to changes in demand.

5.2 Discussion and Implications

Based on the experiences of five 'science and technology small giants' in China, a sustainable innovation model for science and technology SMEs was constructed. The model consists of three levels, and the mechanisms can offer advice on sustainable development using more effective paths to similar enterprises.

The core aspects of the model are the innovation team, innovation principles, and the innovation base. First, human resources are important factors of sustainable innovation in enterprises (Florida & Davison, 2001), and entrepreneurs' innovation desire (Cao et al., 2012), entrepreneurial view (York & Danes, 2014), and CEO's passion for inventing (Strese et al., 2016) are viewed as crucial elements. The innovation team proposed in this study includes all these aspects and should be built based on entrepreneurial, innovative human resources that are constantly improving. The innovation team composition should be flexible yet well-coordinated, and the creative talents within should have an overall vision of the ongoing innovation progress, as well as an entrepreneurial spirit to manage and commercialise the innovation outcomes of the enterprise. Subsequently, to further motivate the innovation team to deliver creative outcomes continuously, a clear system of principles should be formulated to guarantee innovative practices in such enterprises. As science and technology-based SMEs face constant and fast technology upgrades and market changes and because environmental and market adaptability is necessary (Zheng, 2001), an executable process is also essential for supporting sustainable innovation.

Finally, the third essential part of this model is the innovation base, which involves multiple perspectives. Science and technology-based SMEs often risk initial investment shortages (Cao et al., 2012), restrained networking (Muzzi & Albertini, 2014), unavailable intangible resources (Cao et al., 2020), susceptible supply chains, and difficult marketing responses (Caballero-Morales, 2021). Hence, when building on a base such as a successful parent firm or corporation, the enterprises would evolve quicker and smoother than their counterparts. The innovation base consists of a platform that serves as both a technology convergence platform and a technology loss insurance platform; an organisation that clusters innovation resources and manages personnel; investment in both tangible and intangible assets, such as material base and branding; leading products or services that already gained market acceptance; and innovation demand from the macro environment and customers. As the components of the innovation base can be mostly supported by existing successful predecessor companies, science and technology-based SMEs should consider collaboration and investment rather than struggling in isolation (Emilsson et al., 2020). For instance, they can collaborate with well-known enterprises to build a reputation, and subsequently attract investment and open markets, thus promoting sustainable innovation development. When standing on the shoulders of giants, vulnerable science and technology-based SMEs can go further.

The sustainable innovation model developed in this study recognises the importance of human capital, institutional power, and platforms, and thus, can provide precise policy implications for science and technology-based SMEs seeking sustainable innovation development. As China is undergoing a period of transition from manufacturing to innovation development, this study contributes by empirically supporting this transforming process. Previous studies have argued on the importance of human capital in sustainable innovation in science and technology-based SMEs, and this study extends the literature by emphasising the flexibility of creative personnel. This study suggests that an innovation team should comprise flexible talent, so that team building is an ongoing process. The team should be able to incorporate new creative talent at any time and continuously improve.

An overall entrepreneur vision is also necessary to further stimulate innovation growth, protect emotional bonds, maintain a satisfactory corporate culture, and thus, retain the highly mobile crowd as the basis for sustainable innovation. Several studies have revealed the importance of innovation principles, with the belief that the process developed from these principles can solve most of the problems encountered by innovative SMEs (Belkin et al., 2018; Zhang et al., 2021). This study refined the definition of innovation principles by underlining the execution possibility, and proposed that guidelines should be formulated by relevant departments to guarantee executable practices and shifts from traditional to innovation management perspectives. Additionally, this study proposed that when the system is not applicable, these enterprises should improvise through their innovation culture. Further, the fluidity of innovation principles was emphasised, implying that the principles should be a constant improving system.

Recently, literature on how resource foundation supports the sustainable innovation of science and technology-based SMEs has emerged. The profound value of investment and networking foundation is continually discussed. Based on these researches, this study specified the resources support that could be offered by a solid innovation base—not only investment and brand recognition, but also shared intellectual property rights, patents, IT systems, risk bearing mechanisms, and technology loss control. The strength of an innovation platform was also stressed to encourage R&D efficiency, effective communication, innovation incentives, business alliances, and company benefits, which promote sustainable innovation production within science and technology-based SMEs; otherwise, capital chain interruption, technology infringement, and brain drain may disrupt growth.

A key aspect that promotes further innovation development in science and technology SMEs is the leading driving forces. Majority of these enterprises have incubation-worthy ideas but lack the capability to transform them into leading products and technology. An innovation base can provide a material foundation and market advantages, while the customer maintenance experience can be crucial to completing the virtuous cycle of demand-production innovation.

Factors related to mental health of employees could be considered in future research because mental health and well-being of employees is gaining increasing significance in increasing the sustainable innovation in SMEs due to the exposure to vulnerabilities, as seen with the COVID-19 pandemic (Cinar & Bilodeau, 2022).

Antecedents of creative activities vary among industries and market and technological dynamics are quite different, making experience generalisation difficult (Kim & Ha, 2010). Nevertheless, major directions remain noteworthy: a flexible and visionary innovation team, system of executable and flexible innovation principles with the support of organisational culture, and openness to append to innovation bases for a more secure sustainable innovation path. As sustainable innovation is attracting attention worldwide, future studies could also enlarge the research scope outside of China, or initiate comparative studies between SMEs and larger companies.

6. Conclusion

This study developed a sustainable innovation model for science and technology-based SMEs on selected cases. Through a three-level coding of grounded analysis, information gathered from five 'science and technology small giants' was processed to generate a final model from the concepts and categories. The three core categories proposed to be valuable to other science and technology-based SMEs that aim to follow a creative development path comprise the innovation team, innovation principles, and an innovation base. The innovation team should consist of flexible, creative talent with built-in entrepreneurial spirit, and should continually improve personnel capabilities. The innovation principles should be illustrated as an executable and continuous evolving system process, with guaranteed effectiveness and a certain degree of flexibility supported by innovation culture. The innovation base should emphasise the power of an innovation technology platform, innovation organisation, innovation investment, and leading driving forces, all of which could all be supported by business alliances or group companies to assist science and technology-based SMEs in overcoming various difficulties in pursuit of sustainable innovation development. The model depicted a reasonable development route for the sustainable innovation of science and technology-based SMEs, and the empirical results suggested possible policy implications for developing countries that are transforming and upgrading their industrial structures.

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Appendix

Appendix 1. Open Coding Example

Raw data	Concepts
Training provided by the company (a1 Internal training), communication (a2 Internal communication) and foreign cooperation (a3 Foreign cooperation) […] improve the technological innovation ability of employees, especially R&D personnel, in various ways (a4 Technical innovation ability of personnel), accelerate the promotion and application of various new technologies in the company (a5 Promotion and application of new technology) […] The company integrates scientific research resources (a6 Integration of scientific research resources), the R&D incentive mechanism (a7 R&D incentive mechanism), human resource allocation (a8 Human resource allocation), technology management (a9 Technology management) […] and formulated a practical and effective system (a10 Effective system) and implementation measures (a11 Implementation measures).	a1 Internal training, a2 Internal communication, a3 Foreign cooperation, a4 Technical innovation ability of personnel, a5 Promotion and application of new technology, a6 Integration of scientific research resources, a7 R&D incentive mechanism, a8 Human resource allocation, a9 Technology management, a10 Effective system, a11 Implementation measures

[...] cultivate the innovative consciousness of all staff (a34 Innovation awareness of all staff), further improve the technological innovation system (a35 Improve the technological innovation system). Since its establishment, the company has actively advocated for the establishment of innovative consciousness of all staff through organising training and internal discussion (a36 Internal discussion and innovation) […] to make the staff fully realise the importance of innovation and include innovation consciousness in their daily work. The company has set up a technological innovation award (a37 Technological innovation award). The company organises a review of the whole company's technological innovation award every six months (a38 Technology innovation award evaluation). In addition to technical experts as judges, we also invite interested employees to participate in the evaluation and provide material and moral encouragement to the award-winning employees (a39 Material and spiritual rewards) […] The company's innovation includes not only technological innovation (a40 Technological innovation) but also application innovation (a41 Application scheme innovation), business model innovation (a42 Business model innovation), managerial innovation (a43 Managerial innovation), and service innovation (a44 Service innovation).	a34 Innovation awareness of all staff, a35 Improve the technological innovation system, a36 Internal discussion and innovation, a37 Technological innovation award, a38 Technological innovation award evaluation, a39 Material and spiritual rewards, a40 Technological innovation, a41 Application scheme innovation, a42 Business model innovation, a43 Managerial innovation, a44 Service innovation

Appendix 2. Concepts Specification

Concepts	Core Themes
a133 Technical consultant, a134 Consulting companies, a13 Industry experts	b1 Flexible talent
a62 Introducing talent, a79 Qualified graduates join the company, a118 Personnel recruitment process	b2 Introduction of competent personnel
a65 Talent strategy, a85 High proportion of R&D personnel, a8 Human resource allocation, a57 Construction mechanism of R&D talent team	b3 R&D team building
a1 Internal training, a2 Internal communication, a68 Complete training system, a78 Personnel training	b4 Organising training
a122 Self-learning, a36 Internal discussion and innovation	b5 Self-learning
a64 Improve the knowledge structure of R&D personnel, a4 Improve the technical innovation ability of personnel, a5 Promotion and application of new technologies, a63 Improve the quality of employees	b6 Personnel capacity improvement
a73 Participate in industry exhibitions at home and abroad, a75 Participating in industrial alliances, a76 Industry associations, a77 Application forums	b7 International exchange
a88 Corporate governance, a106 State-owned vs private enterprises	b8 Flexible operation mechanism
a89 Excellent professional managers, a90 Excellent CEO, a91 Entrepreneurship	b9 Entrepreneurship
a130 Cohesion activities, a61Talents retain by emotion, a67 Good working environment	b10 Humanistic concerns
a92 Future development strategy, a93 Overall development goals for the current year and the next two years	b11 Overall development strategy and plan
a94 Specific plans and measures for the development of the company, a95 Innovation development plan	b12 Innovation strategy and plan
a10 Effective system, a69 Efficient incentive system	b13 Effective system
a38 Evaluation of the technological innovation award, a28 Coordinated R&D mechanism, a107 Regular technical innovation meeting	b14 R&D mechanism
a11 Feasible measures, a14 Standardised process-oriented system	b15 Implementable process

a35 Complete the technological innovation system, a13 Continuously improve the R&D management process	b16 Process improvement
a34 Innovation awareness of the whole staff, a147 Establish a sense of innovation, a148 Recognise the importance of innovation, a149 Innovation consciousness	b17 Innovation consciousness
a56 Corporate culture, a124 Rules, a125 Team, a126 Perseverance, a84 Competitive consciousness	b18 Organisational culture
a43 Management innovation, a44 Service innovation	b19 Service mode innovation
a42 Business model innovation, a41 Application scheme innovation	b20 Business model innovation
a103 Patent application, a104 Software copyright	b21 Intellectual property right
a131 Industry standards, a132 Patent Standard	b22 Patent standard
a40 Technological innovation, a32 Technical versatility, a31 Continue to improve the product development platform	b23 Technology innovation platform
a86 IT system, a87 CQ tools	b24 IT system
a96 Risk of losing core technical personnel, a97 Risk of core technology leakage	b25 Technology loss risk
a98 Confidentiality system, a99 Confidentiality agreement, a100 Security system, a101 Control process of technology research and development, a102 Reduce dependence on core technical personnel, a105 Legal weapons	b26 Technology loss control
a12 Specialised research and development institutions, a16 Department of technology development, a9 Technical management	b27 Innovation and development department
a120 Organisational structure, a121 Each performs its own functions	b28 Each performs its own functions
a70 Cooperation with domestic research institutes, enterprises, and institutions, a74 Undertake national innovation projects, a136 R&D outsourcing, a137 Joint laboratory	b29 Strategic alliance
a3 International cooperation, a71 Cooperation with foreign scientific research institutes, enterprises, and institutions	b30 International cooperation

a6 Integrating scientific research resources, a144 Integrating technical resources, a145 Comprehensive service capability, a146 Resource allocation	b31 Resource integration
a25 Feasibility analysis, a26 Project approval, a27 R&D node review, a33 Improvement of R&D efficiency	b32 R&D efficiency
a22 Linkage between R&D and marketing departments, a29 Effective information feedback	b33 Effective communication
a45 Innovation incentive mechanism, a46 Core technical personnel encouragement by equity, a7 R&D incentive mechanism	b34 Innovation incentive
a37 Technological innovation award, a39 Material and spiritual rewards	b35 Technological innovation incentive
a48 Provide career development planning, a49 Promotion opportunities, a53 Professional title evaluation, a54 Appointment, a59 Career retention	b36 Promotion
a55 Industry competitiveness, salary, and benefits, a58 Good security conditions, a66 Attractive pay, a60 Treatment retention	b37 Salary and treatment
a119 The survival of the fittest, a50 Scientific and fair staff performance appraisal management mechanism	b38 Staff assessment
a47 Implementation of annual performance awards, a51 Performance appraisal linked with performance rewards, a52 Staff salary adjustment	b39 Linkage of assessment and treatment
a108 Financial data and financial indicators, a114 High-profit margin industry	b40 Profitability sustainability
a80 Continuous R&D investment, a81 High R&D investment, a83 Continuous improvement of scientific research conditions	b41 High input
a138 Depreciation of fixed assets, a139 Test environment, a140 Testing laboratory, a141 Testing instrument	b42 Research resources
a142 Real estate, a143 Rental property	b43 Real estate property
a128 The popularity of 5G in the future, a17 New products and technologies	b44 New products and technologies
a18 Leading technology and products, a72 The foresight and advanced nature of technology, a82 Domestic leading core technology	b45 Leading technology
a123 Explore potential customers, a127 Overseas market	b46 Develop customer

	market
a115 Leading market position, a116 Market pioneer	b47 Market leading
a129 Competitors, a15 Keep competitive advantage in the market	b48 Market competition
a109 The global software industry growth, a110 The overall rapid development of China's software industry, a111 The growth trend of the global information security industry, a112 The growth of China's information security industry	b49 Industry growth
a113 Industrial policy support, a117 Innovative atmosphere	b50 Innovation policy
a19 Market orientation, a20 Potential market demand, a21 Sales feedback, a24 Demand collection	b51 Customer orientation
a23 Meet market and customer needs, a30 Modify the fit between product and market demand	b52 Meet customer needs