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Impact of Crisis on Sustainable Business Model Innovation—The Role of Technology Innovation

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Abstract: The transformation of old and new technologies, the normalized crisis situation, and global economic integration blur industrial boundaries and cause the business pattern to fluctuate and become unsustainable, especially when considering the impact of the COVID-19 pandemic. This study focuses on crisis situations and combines the types of technology innovation (introduction, socialization, and differentiation) and sustainable business model innovation (efficiency, novelty, and co-benefit innovations) to theoretically analyze the dynamic impact of technology innovation on different types of sustainable business model innovations. Using a multi-case comparative analysis method, typical enterprises are selected as the sample cases. This study discusses the influences of different technology innovation schemes on sustainable business model innovation in different crisis situations. Enterprises should consider introducing technology for rapid value updates to maintain an efficient business model in an urgent production factor crisis, search for valuable and scarce technical components or introduce other entities to facilitate technical cooperation and form a novel business model in a market environment crisis, and use big data, artificial intelligence, and other technologies to create co-benefit business model innovation in a business ethics crisis. The conclusion guides enterprises and provides a framework for the optimal technical scheme under the corresponding crisis.

Keywords: crisis; technology innovation; sustainable business model innovation; market environment

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1. Introduction

Enterprises encounter an unsustainable and predictable dilemma in designing their business models due to the advancement of several scientific and technological revolutions, the wave of economic globalization, old markets that are replaced by new ones, and the interaction of multiple stakeholders. Since the COVID-19 outbreak in 2020, Chinese enterprises have endured substantial economic shocks and industrial changes. Eight hundred thousand Chinese enterprises ceased trading in the first half of 2020. Online education, telecommuting, and online medical care have become trends. The supporting information technologies such as 5G, cloud computing, and video conferencing are continuously developing, which pressures enterprises to reinvent their operational business models. The organizational resilience of logistics enterprises is enhanced by factors such as the introduction of delivery robots equipped with facial recognition, 5G, and other technologies which improve the digital and intelligent elements of logistics business models. Up to 2021, the volume of business conducted by logistics enterprises had increased by 29.9% yearly. Alibaba, Tencent, and other internet companies have pioneer advantages in technology and home field advantages such as the development and application of innovative technology. In addition, they expand online education, jointly control the national epidemic special network platform, develop communal epidemic prevention systems, and extend multiple

areas of business. Gree, an air conditioning manufacturing enterprise in China, relies on big data, artificial intelligence, and other technologies to integrate online, after-sale services and offline experiences to establish an integrated and new retail model. In addition, Gree introduces cloud services, electronic price tags, and other auxiliary facilities to promote the construction of digital stores. It experienced a contrarian recovery in 2020, and its net profit has increased quarterly. Its fourth quarter's turnover broke an all-time record. With the global penetration and the in-depth development of science and technology, the market environment reflects more unstable factors which are unsuitable for economic growth. Therefore, enterprises are facing normalized crises in addition to the subjective adjustments of the internal organizational factors of enterprises [1]. Nevertheless, many enterprises are still immature in their response to crises, and fall into the passive defense thinking of denying, evading, and weakening crises [2]. Thus, this research intended to merge positive handling methods in crises that can add value to enterprises under different crisis situations through some effective crisis-handling strategies, such as through different forms of technology innovation, to resolve the consequences of a passive response, which can induce more economic losses under crisis situations. Consequently, it is essential to analyze how enterprises can positively convert crises to opportunities and achieve sustainable business model innovation.

Organizational crisis strategies gradually change the ways in which the business world operates. Most scholars focus on the relationship between technology and sustainable business model innovations [3,4]. Crisis research mainly focuses on public and product crises and fails to explain the internal logic of crisis and sustainable business model innovations [5,6]. However, technology innovation bridges the gap between crisis and sustainable business model innovation. On the one hand, technology innovation constantly drives the systemic innovation of business models, from resources, information, and in other ways. On the other hand, the vigorous development of big data, cloud computing, artificial intelligence, 5G, and other technologies provide new environments and technical support for a timely and effective response to crises. In today's normalized crisis, technology innovation is one of the most efficient means with which to promote the sustainable adjustment, optimization, and innovation of business models and to sustain enterprises [7].

Most of the research conducted on crises has focused on the perspective of consumers and the market, such as a crisis' impact on an enterprise's market performance [8], consumer transfer [9], brand image building under various crisis scenarios [10], ignoring the impact of a crisis on an organizational level. Recently, more and more studies have confirmed the important role of crises on sustainable business model innovation [11]; however, business model innovation is a value-adding process and needs to be promoted steadily. Through the commercialization of technology, the value added through business innovation is transferred to the long-term contribution of the enterprise or to more important elements. Consequently, technology innovation plays a crucial role in the realization of sustainable business model innovation [12]. Nevertheless, the existing literature does not pay attention to the existing research on the impact of crises on the process of sustainable business model innovation through technology innovation. In order to further enrich the literature on sustainable business model innovation, it is of great theoretical and practical value to better answer the question of how Chinese enterprises should act in regard to technology innovation during a crisis and how they can eventually achieve sustainable business model innovation.

2. Literature Review

2.1. Literature Review on Crisis

2.1.1. The Concept of a Crisis

Until the 1960s, the initial study of crises did not derive from the management field, but from the political field, and, thereafter, crisis research expanded into the economic and social fields. Crisis research became especially prominent for both scholars and practitioners in the 1980s, with the increasing risk of enterprises' competitive environments.

At the micro-enterprise level, crises are divided into in five representative categories: Foster defines a crisis as an urgent need for quick decisions, a lack of trained employees, sufficient material resources or time to complete the risks [13]. Rosenthal and Pijnenburg outline the broader concept of crises as situations with a serious threat, uncertainty, and weak crisis awareness [14]. Barton defines a crisis as an uncertain event that may cause great damage to products, services, employee benefits, and organizations [15]. Green defines crises as out-of-control events [16]. Lerbinger summarizes the three major features of an event that develops into a crisis. First, the incident poses a threat to the business and hinders the realization of its goals. Second, if the business fails to act, the situation will irreversibly deteriorate. Third, the event is mutated [17].

Scholars commonly define a crisis as an event that is sudden and a threat. However, they differ in their definitions based on their understanding of the root cause and the results of the crisis. The uncertainty caused by the changes in the external environment may also be derived from an enterprise's internal environment. The outcome of the crisis emphasizes that there is an uncontrollable situation for an enterprise which threatens its basic survival, employee benefits, and its development goals. This study proposes a comprehensive definition of an enterprise crisis: a crisis develops when the enterprise does not control the uncertainty caused by internal or external environment changes timeously, and, therefore, its operations deteriorate to create an irreversible emergency.

2.1.2. Crisis Theory

This study divides the representative perspectives on crises into the following four categories: First is crisis system theory, which revolves around the integrity and dynamics of the operational system. It indicates that a crisis outbreak is mostly the harmful result of an enterprise ignoring the operational risk that a crisis, caused by a change in the external environment, is likely to evolve into. The second perspective involves the cause of crises, such as rapid changes in the external environment and inefficient internal management. Based on Porter's model, an external crisis is generally composed of inter- and intra-industry competition, alternative product challenges, and supplier deviations. The third perspective is the theory of crisis diffusion, which examines the path of a crisis, especially the media attention, because the media can directly accelerate a capital crisis and destroy a corporate image. The fourth view is crisis risk theory, which is the most intuitive expression of an enterprise risk. These enterprise risks are divided into traditional (e.g., enterprise operational mistakes and external and cross-cultural risks) and emerging (e.g., technology subversion, disorderly spread of business models, and value chain fractures) [18].

Although enterprise crises are approached from different perspectives, in essence, they are similar and are classified based on integration. In crisis theory, the four views of system, cause, diffusion, and adversity are the most representative. The theory is enriched by the addition of causes, the scope of influence, and characteristics, and has evolved from the concept of understanding to the construction and application stages of crisis theory. The crisis system and cause structure theories emphasize the constraint of the external environment in terms of potential competition, loss of target customers, product backlogs, poor capital turnover, and low employee morale and present a systematic and holistic chain reaction. An external environmental crisis can also manifest as a lack of suppliers because poor supply quality affects the enterprise's operations. There are corresponding conceptual interpretations for crises in different subjects; however, these classifications diverge or overlap and are strongly interconnected. Therefore, it is necessary to further distinguish, extract, and summarize crisis types.

2.1.3. Characteristics and Trends of Crisis Research

Scholars first subdivided crises into a public crisis in the political field and an enterprise crisis in the economic field. They have constantly enriched the relevant theories of crisis in terms of definitions, categorizations, process performance, causes, and crisis management. Research on crisis stages classifies it as systematization, organization, and technology.

These systematization characteristics confirm that scholars categorize crisis research as a business process. Enterprises are increasingly encountering crises, and those in different industries and of varying sizes have significantly different responses. The characteristics of technology indicate that scholars gradually implement crisis responses at the technical level, such as establishing crisis warning systems and crisis innovation departments. However, this research is still theoretical and unsuitable for enterprises; therefore, it is difficult to summarize the crisis response from the system level of redundancy problems. The focus on whether the crisis should be embedded in the enterprise business model has gradually reached a unified understanding, whereas the integration of the crisis and the enterprise's operations lacks theoretical support and requires further construction and verification. As the economy develops, more realistic elements must be integrated into crisis research.

2.2. Literature Review on Sustainable Business Model Innovation

2.2.1. Defining the Business Model

Scholars researching the business model concept have not yet reached a consensus, and it is derived from the following four perspectives:

From the perspective of profit, the business model is defined as the way in which the organization can make a profit, which is the organization's fundamental goal. Accordingly, Mahadevan describes the business model as an organic coupling of value, capital flow, and logistics [19]. Schmitt divides the business model into three sources: profit output mode, profit planning, and continuous competitive advantage [20]. This perspective does not distinguish between the elements of a business model, which are enumerated horizontally. The definition of a business model is relatively fragmented, which is a result of the early stage research on business model practice.

From an operational perspective, the business model is the external perception of the organizational operational structure. It focuses on the internal long-term mechanism of enterprise value creation and the foundation of the organizational structure. Magretta defines it as the sum of collaborative business layouts that drive enterprises to create value and open the value chain [21]. Zott views the business model as a network of operations driven by enterprises, suppliers, users, and other stakeholders, which is integrated into the business ecosystem [22].

From a strategic perspective, the business model is reflected in the overall investigation, involving market value transformation, differentiated competitive advantages, and sustainable responses. According to Dubosson-Torbay et al. the attributes of the business model enable enterprises to generate continuous profit streams, create a refined architecture for target groups, and ultimately deliver capital value [23]. Schlegemilch et al. found that the business model corresponds to the strategic planning of the organization, and that the strategy and vision of an enterprise are established and developed through the business model [24]. Enterprises can understand and focus on the business model elements, which is more practical.

From a comprehensive perspective, the business model is regarded as the optimization and innovation of an organization's operational perception, profit logic, and strategic investigation, which is reflected in the integration and direction of the key path of the business system. The new perspective removes the shackles from the business model that only describes an enterprise's operational perception and profit logic. It is not bound by the constraints of a strategic summary of all the levels, thereby eliminating the isolated cognitive obstacles and thus comprehensively improving the connotation of the business system operations from the overall consideration level of the system and the previous perspectives. Osterwalder et al. summarized the actual quantification of a business model in terms of logical and conceptual tools and established a business canvas model which includes four modules and nine elements, which may be the pinnacle of business model innovation [25]. The business model, from a comprehensive perspective, is more aligned with the trend of community consciousness and marketization of production factors and with the changes and laws of value flow in economic and social environments.

2.2.2. Business Model Innovation

Scholars are increasingly aware of the complexity of business model innovation and the challenges of the external environment. Studies on business model innovation mainly focus on the factor integration and pre-variables of business model innovation (i.e., the driving factors of innovation).

Certain scholars consider technology as the core driver when defining business model innovation. For example, Chesbrough proposes that business model innovation is a process whereby enterprises start with their core technology and connect it to economic value [26]. Other perspectives consider value chains, for example, Lee shows that big data technology is of great significance to business model innovation in terms of value proposition accuracy and business activity change [27]. Certain scholars start with business model governance and embedded technology drivers; for example, Dmitriev proposes that the connection between technology and business model innovations can inspire the operation and development of enterprises, which are the heuristic thought processes of the operation's personnel and management. In addition, technology innovation must be accompanied by business model innovation to release the economic value contained in it [28]. Zhang et al. divides business model innovation into three stages: original, induced, and imitation. They reveal the irreplaceable nature of technology innovation to business model innovation based on its stage characteristics and action mechanisms [29].

2.2.3. Classifying Business Model Innovation and Sustainable Goal

There are two main perspectives for the classification of business model innovation. One is according to the degree of business model innovation, and the other is according to the different perspectives of value creation.

According to the degree of innovation, Mahadevan points out that enterprises with different characteristics need to adopt different business model innovations. New enterprises should adopt strategic innovation business models. However, enterprises that become industry leaders should adopt obstruction business model innovation, and trend creators should adopt entirely new business model innovation [19,30]. Andreini, based on the theory of modularity and changeable degrees in the core logic of the business model, proposes four types of business models: modularity, architectural, incremental, and radical [31].

Scholars have examined value creation from three perspectives: factor, value chain, and system innovations. Factor innovation research finds that business model innovation is realized by changing and developing one or more elements, which include the four aspects of customer value proposition, profit model, key resources, and key processes [32]. Regarding innovation in the value chain, Hossain divides business models into four types: knowledge shaping, strategic reorganization, system evolution, and process change [33]. As research on business models increases, scholars have begun to approach business model innovation from a comprehensive perspective. The earliest business model innovation studies were conducted by Zott and Amit, who divided business models into four major types: efficient, complementary, trapped, and novel [34]. They considered Schumpeter's two sources of value creation (efficiency and innovation) and focused on both efficient and novel business model innovations [35]. Efficiency considers simplifying the business and transactions, information asymmetry barriers in business activities, fault tolerances in executing business transactions, and upgrading the organization's existing business model to improve transaction efficiency. Innovation includes enterprises' networks and new trading partners from a broader perspective, adopting new ways to promote business transactions, and designing and improving new trading and incentive mechanisms. Zott and Amit's classification is widely recognized and adopted by scholars.

However, scholars examining business model innovation mainly focus on the integration of innovation elements and pre-variables and the effectiveness of technology innovation in expanding business model innovation. They increasingly conduct follow-up research on two business models which help to keep a business model sustainable: efficient and novel types. For example, questions worth examining are whether the efficient and

novel business model innovations can still be applied to the changing environment based on technology changes, and whether there are new business model innovation types or some that should be discarded.

In the past decade, driven by organizations' social responsibility practices, a new value proposition has led to a new sustainable business model, the co-benefit business model, which has gradually become an important topic in academic circles and in the industry [36]. The theoretical study of co-benefit business models considers background rationality and operations feasibility. However, scholars have failed to form a unified understanding of the model's innovation trend and mostly follow the latest trend in theory and practice, which is to emphasize the co-benefit business model in terms of the double attributes of social and economic values.

2.3. Research on the Relationship between Crisis and Technological and Sustainable Business Model Innovations

2.3.1. The Relationship between Crisis and Technology Innovation

Of the studies conducted on the relationship between crises and technology innovation, the most famous is Schumpeter's, who explains why the capitalist economic crisis occurs periodically from the perspective of long-wave theory, that is, continuous innovation directly leads to the cyclical occurrence of economic crisis [37]. Johnson examines technology innovation based on Schumpeter's research [38] and finds that the economic crisis is the key driver of innovation. According to long-wave theory and the historical verification of the previous industrial revolutions, the recovery of each economic crisis ultimately depends on major technology innovation.

Many scholars prove the relationship between crisis and technology innovation from the perspective of the digital industry and technology. First, digital breakthroughs emphasize the transformation, integration, and adoption of new technologies. For example, Doyle and Conboy find that enterprises use online digital approaches to promote products and services to overcome a pandemic's barriers [39]. Second, digital transformation emphasizes changes in the digital economic systems and architecture levels which maintain business sustainability to enhance organizational resilience [40]. The digital leap requires more technology and global controls. The crisis situation forces value networks, business processes, and innovation capabilities to transform by using digital technology solutions (e.g., big data and cloud computing) [41].

Scholars examine the feasibility and necessity of technology innovation to deal with unexpected crises, combined with examples and the environment. For example, Lee and Trimi believe that combining sustainable technology innovation with value creations such as new ideas and strategies and independent ecosystems for real-time, on-demand decision-making is the most effective way to deal with a crisis [42]. In summary, the research related to crisis and technology innovation is more popular, and Chinese researchers focus less on the causes of technology innovation such as crises. The relationship between technology innovation and a crisis is object-oriented and undeveloped. Although it accords with the recent environmental trend, it has not been organized or standardized and scholars have not yet reached a consensus.

2.3.2. The Relationship between Crisis and Technological and Sustainable Business Model Innovations

Scholars mainly study the relationship between technological and business model innovations from different theories or industry perspectives; for example, Ramaswamy examines the relationship using the theory of value co-creation [43]. Kiel et al. consider the manufacturing industry [44] and find that technology innovation has a significant positive effect on sustainable business model innovation. Scholars research biomedicine and find that sustainable business model innovation has a driving and incentivizing effect on technology innovation [45]. In addition, scholars focus on the mutual evolution mechanism of both innovations [46–48].

Scholars researching the relationship between crisis and technological and business model innovations mainly conduct case studies from the industry perspective. The more industry and service industry oriented the studies are, the more research is conducted on the combined effect of technological and business model innovations to cope with the changes in the external environment, which belongs to the category of primitive results. Cefit et al. took the manufacturing industry as an example and, through an analysis of the original and comprehensive samples of enterprises, found that any form of innovation introduced by enterprises in the crisis, such as technology innovation, would weaken the negative impact of crisis, strengthen the crisis response ability and stability of enterprises, and prolong the life cycle of enterprises [49]. Yin took the wood industry as an example and found that the crisis brought opportunities for technology innovation in the industry. The crisis can not only promote enterprises to overcome difficulties through technology innovation, but also help reduce the cost of technology innovation [50]. In the research of crisis and business model innovation, some scholars argue that a business model is driven by the innovation caused by an explicit crisis [51,52]. Morkunas et al. confirm the relationship between crisis and technological and business model innovations. Their results show that encryption technology eliminates structural contradictions caused by the operating mode of chain retail enterprises, mainly because "decentralized redistribution can be used to build chain response mechanisms with low latency and full coverage, to realize the organic business model" [53]. Most scholars analyze the positive impact of technology innovation on business model innovation under crises circumstances. The innovation and application of technology can play a key role in helping enterprises to adapt to a turbulent environment [54,55]. However, a common analysis and interpretation of the issues related to the relationship construction, such as the operation mechanism and logical elements, are still needed.

To sum up, although scholars define the enterprise crisis from different perspectives and divide the crisis types according to different theories, it can be found through comparisons that, although there are differences in the division of the crisis, there also exist similarities and overlaps among these divisions of the crisis. Consequently, it is essential to thoroughly consider the situation of the enterprise and further identify and summarize the crisis types of the enterprise. In addition, through many case studies in practical research, it is found that most enterprises rely solely on the technology emergency department to deal with all crises, and that its effect is not good. Therefore, it is necessary to form a systematic method of thinking and to make decisions at the organizational level when confronting enterprise crises [56], pay attention to resolving redundancy issues, and analyze the relationship between crises and enterprise business model innovation. Research on business model innovation has progressively widened from an early single perspective to a more comprehensively and systematically organizational level, focusing primarily on the positively driving factors of business model innovation [57], the form of business model innovation [58], and the important industry direction of sustainable business model innovation, which is put forward as a new concept in the interdisciplinary research field of sustainable development and business model innovation [59]. Academic research on sustainable business model is still in the initial stage, and the innovation trend and dimension division under this model have not reached an agreement, which still needs to be further analyzed. According to the existing research literature and practice, the internal and external environment of the enterprise will have an important impact on the sustainability of its business model innovation. Some scholars have affirmed that the crisis factors in the internal and external environment of the enterprise have a negative effect on the sustainability of its business model innovation [60]. At the same time, technology innovation can undermine the impact of the crisis on the enterprise and guarantee that the enterprises' business model innovation reaches a sustainable stage. Nevertheless, little research has been conducted on the relationship between crisis and sustainable business model innovation. The specific operating mechanism and internal logic relationship need to be further analyzed and clarified so as to enrich the theoretical research field of crisis

and enterprise operation and provide practical suggestions for enterprises' crisis reaction and management of sustainable business model innovation. Combined with the practical background and the current academic gap, this study considers and attempts to solve the following questions: Can enterprises use homogenization technology to settle the specific crises they face? In a particular crisis, which technological and economic choices are suitable for enterprises to make? What type of sustainable business model will enterprises achieve with different technology choices?

3. Study Design

3.1. Study Methodology

This paper adopts a multi-case exploratory analysis method based on rooted theory. The main reasons for this are as follows: First of all, considering the research questions and the research objects, this study mainly explores the relationship mechanism among crisis, technology innovation, and sustainable business model innovation. Crisis is considered as a complexly contextualized concept, and a multi-case study based on rooted theory is a more appropriate research method to analyze the complexly contextualized study issue, which is suitable for answering questions about the processes and mechanisms, as well as the "how", and for digging out the theoretical logic behind the phenomenon to clearly demonstrate the dynamic impact of different technology innovations on different types of sustainable business model innovation during a crisis. Secondly, there is a lack of theoretical support to address the coupling relationship between crisis and sustainable business model innovation in this study, and a case study can help develop new theories and enrich existing theories by analyzing numerous cases and identifying some undiscovered variables or relationships. Lastly, from an overview of the existing studies, the crisis research primarily adopts quantitative analysis methods such as questionnaire analysis and empirical analysis, which mostly focuses on single typical industries with a single point of view and easily distorted data, and the universality and commonality of the research results are not sufficient to cover most industries. This article adopts a multi-case exploratory research method based on rooted theory, which overcomes the limitation found in previous scholars' method of focusing on a single industry, makes the research more widely applicable, provides some guidance for future research on crisis response solutions in various industries, and effectively demonstrates the holistic, dynamic, and dialectical nature of the research content, which helps to form new concepts and theories.

3.2. Case Selection

In order to better fit the research questions and reflect the impact of the crisis on sustainable business model innovation, we applied the following four criteria to select enterprise cases (see Table 1). The first criterion is case typicality; thus, we selected enterprises which were in the leading position or were regarded as the top competitors in an industry. At the same time, these enterprises had to experience many crisis events and, accordingly, have many risk-reducing abilities in accordance with the crisis scenarios. The second criterion was case heterogeneity, which reflects that enterprises come from three major industries including e-commerce, manufacturing, and social media. Consequently, cross-industry cases can improve the universality of research and help to examine the common technical logic of crisis responses to enhance the robustness of the research. The third criterion was the convenience of data. Enterprise information disclosure is open and transparent, and the industry and scholars conduct longitudinal research on the enterprises' technological and business model innovations. Accordingly, the relevant and accessible literature, interviews, monographs, and news reports are particularly substantial, which enhances the convenience and authority of this study's collected data. Combining the above criteria, this research selects large enterprises as cases such as Alibaba, JD, Zto, and Gree. The specific information of companies and platforms mentioned in the article are specified in Table 1.

Table 1. Case company/platform profile.

Company Full Name	Creation Time	Company Location	Major Businesses
E-commerce Industry			
JD	1998	Beijing, China	Online shop, logistics, finance, etc.
Alibaba	1999	Zhejiang, China	E-commerce, logistics network, new retail, cloud computing, etc.
Vipshop	2008	Guangzhou, China	Online sales of brand discount goods on the internet, covering major categories such as clothing, shoes and bags, beauty and other products
ZTO	2013	Shanghai, China	Domestic express, international express, etc.
Pingduoduo	2015	Shanghai, China	Third-party social e-commerce platform focusing on Customer To Manufacturer (C2M) group shopping
Taobao	2003	Zhejiang, China	The online retail trading platform launched by Alibaba
Alipay	2004	Zhejiang, China	Third-party payment platform, mainly for mobile payment, electronic payment
Manufacturing Industry (Information and Communication Technology)			
TCL Technology (TCL)	1982	Guangdong, China	Semiconductors, electronic products and communication equipment, new optoelectronics, liquid crystal display devices
Huawei Technoligies (Huawei)	1987	Guangdong, China	IT, radio, microelectronics, communications, routing, program-controlled switches, etc.
China Telecom	1995	Beijing, China	Fixed communication business, mobile communication business
IFlytek	1999	Anhui, China	Value-added telecommunications services; computer software and hardware development, production and sales; electronic products, computer communication equipment research and development, etc.
China Mobile Communications Group (China Mobile)	2000	Beijing, China	Fixed communication business, mobile communication business
Xiaomi	2010	Beijing, China	Digital products, software, etc.
Manufacturing Industry (Electrical Manufacturing)			
Changhong Electric (Changhong)	1958	Sichuan, China	Household appliances, automotive appliances, electronic products and spare parts, etc.
Midea	1968	Guangdong, China	Household appliances, etc.
Galanz	1978	Guangdong, China	Home appliances, microwave ovens
Haier	1984	Shandong, China	Development and sales of refrigerators, air conditioners, electric freezers, washing machines and other home appliances
AUX	1986	Zhejiang, China	Home appliance, electric equipment, medical, real estate, financial investment
Gree Electric Appliances (Gree)	1991	Guangdong, China	Home appliances, mainly air conditioners
Chigo	1994	Guangdong, China	Home appliances, mainly air conditioners
Manufacturing Industry (Automotive Manufacturing)			
BYD	1995	Guangdong, China	Automotive, rail transportation, new energy and electronics
Tesla	2003	Palo Alto, USA	Electric vehicle sales and leasing business, energy and energy storage business, etc.
Contemporary Amperex Technology Co., Limited (CATL)	2011	Fujian, China	Lithium-ion batteries, lithium polymer batteries, fuel cells, power batteries, etc.
Nio	2014	Shanghai, China	High-performance smart electric vehicles with the ultimate user experience
Xiaopeng	2014	Guangdong, China	Main production of cars
Manufacturing Industry (Petrochemicals)			
China National Offshore Oil Corporation(Cnooc)	1982	Beijing, China	Oil exploration, production and sales
Sinopec	1983	Beijing, China	Oil trading, oil extraction, storage, transportation and chemical industry, etc.
Asea Brown Boveri (ABB)	1988	Zurich, Switzerland	Power technology, automation technology and oil/gas/petrochemical industry and robotics

Table 1. *Cont.*

Company Full Name	Creation Time	Company Location	Major Businesses
Social Media Industry			
Tencent	1998	Guangdong, China	Media platforms, online advertising, financial technology and corporate services
Sina	1998	Beijing, China	Mobile Value Added Services (MVAS), internet video, music streaming, online games, photo albums, blogs, email, etc.
Baidu	2000	Beijing, China	Search platform, cloud services, etc.
Aliyun	2009	Zhejiang, China	Technology facilities to support digitization and intelligence launched by Alibaba
Sina Microblog	2009	Beijing, China	Sina's social media platform and software for sharing daily life
QQ	1999	Guangdong, China	A live chat tool launched by Tencent
WeChat	2011	Guangdong, China	An instant messaging software launched by Tencent

3.3. Text Collection

3.3.1. Text Collection Method

This study uses a multi-channel method to collect data in the form of text which is divided into internal and external text. The internal text is obtained from official books, executives' interviews, websites, and other official public sources. The external documents include all types of public information, such as, for example, from online companies, such as Baidu, Sina, and Zhihu, and literature databases. Multi-channel text sources improve the richness of data and provide a solid foundation for coding analyses. During data collection, the text is constantly evaluated, compared, considered, and reviewed, which improves the final data used. Furthermore, collecting data from multiple sources facilitates the conducting of a cross-inspection to ensure the authenticity and reliability of the collected text. At the same time, although there is a lack of primary data from in-person interviews due to the constraints of the research, the content from the public interviews of the top management of these companies can represent their true views, which is what this study hopes to attain; therefore, the secondary data collected in this paper does not affect the reliability of the study.

3.3.2. Text Analysis Method

Scholars have commonly used root theory to evaluate the overall factors, theoretical models, and the conduction paths of academic topics, and it has gradually become a scientific and representative method to overcome problems in qualitative research in which theoretical systems are difficult to explain or are lacking. This study considers the logical mechanism of a crisis and technological and business model innovations. Therefore, theoretical research studies which include case data from different industries and years are scarce, and identifying the internal common logic is difficult. Accordingly, this study does not follow the traditional research methods, such as questionnaire surveys, and instead considers the coding approach of the rooted theory which includes three main steps: open coding, spindle coding, and selective coding; inducts, deduces, and refines the scope of the relevant concepts; and establishes and develops new theories, and also eventually adopts a theoretical model with a supporting case study and examines the influence of a crisis on technological and business model innovations. The research process in this paper is shown in Figure 1.

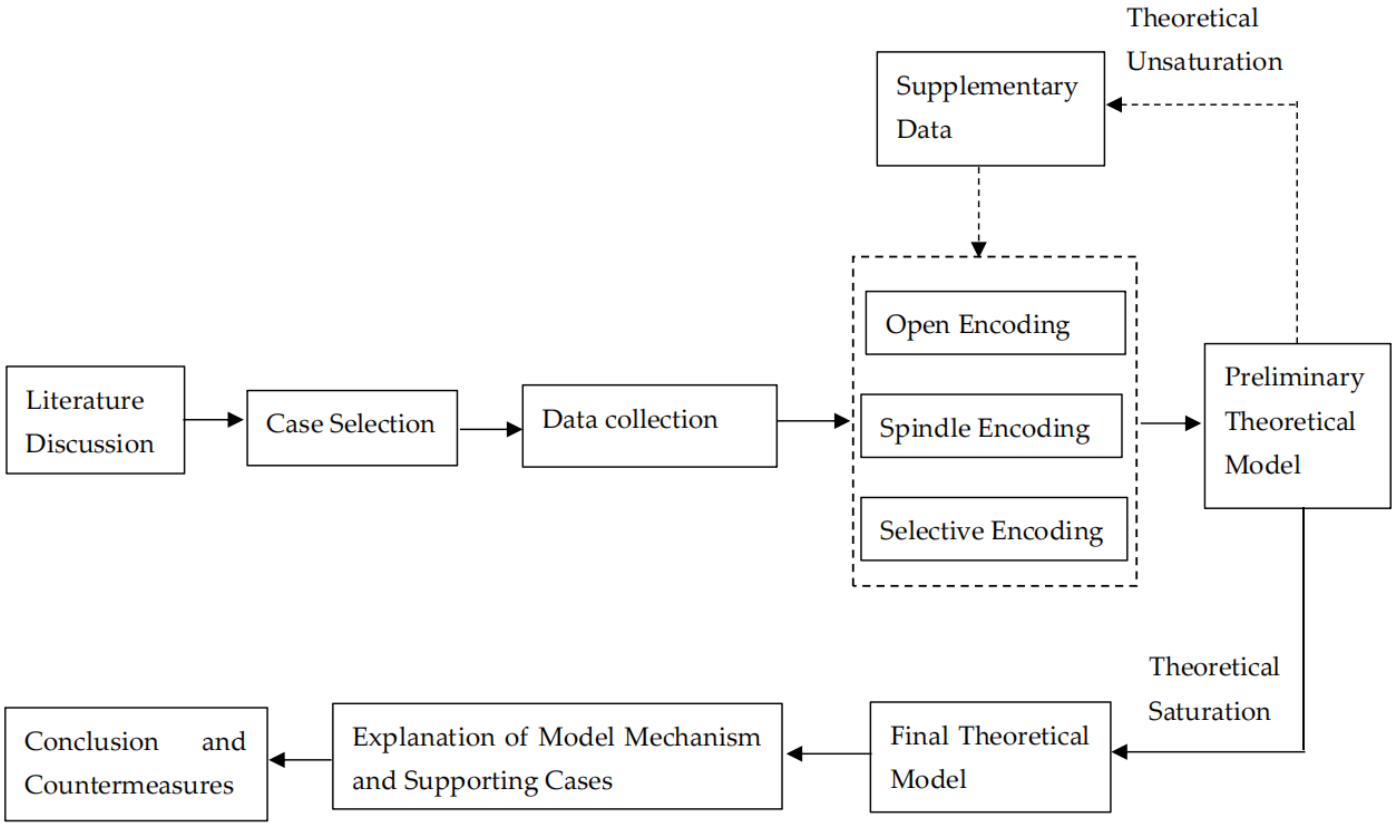


Figure 1. Research process.

4. Study Results and Encoding Analysis

4.1. Open Encoding

The first step of the rooted coding method is to examine the original text and utilize emerging, new, and typical phenomena to gradually form a conceptual definition and classifies similar or related concepts into subcategories through repeated alignment and classification. Open coding strictly follows the procedural guidelines of "labeling—defining phenomenon—defining concept—discovering category" to ensure that the research is scientific and rigorous. This study obtains 33 entries and concepts and 17 categories with open coding.

4.2. Spindle Encoding

The second step is spindle coding, which allocates classes to the concepts and categories which are then clustered into more advanced categories and examines the possibility of a potential logical relationship among categories to extract a generalized core category. The extraction, induction, and integration of spindle coding procedures identify nine main categories, which are: production factor, market environment, and business ethics crises; introduced, socialized, and differentiated technology innovation; and efficient, novel, and co-benefit business model innovations. Among them, introduced technology innovation refers to the process of the digestion, absorption, and reinvention of introduced technologies and products by enterprises through reverse engineering and other means [61]. Socialized technology innovation is a creative social action oriented to social needs and social problems, primarily initiated by social organizations or promoted in multifaceted cooperation with government and profit-making organizations, which constitutes a new mechanism for the government with which to respond to social challenges and promote social development [62], and it can be a product, a technology, an action method, or a business model. Differentiated technology innovation, on the other hand, refers to a company's efforts to be unique in its industry in certain aspects that are widely valued by its

customers. Combining the definition and classification of technology innovation in the relevant literature [61–63] and the theory of technological capability (with the enhancement of technological capability, the evolution of the trajectory model of technology innovation should gradually evolve from imitative innovation to cooperative innovation and independent innovation) [64], a sub-category hierarchy of technology innovation can be obtained (see Figure 2). The business model innovation can be divided into efficiency type and novel type from the perspective of the transaction mode within the industrial ecosystem, and the relationship between the two is neither orthogonal nor exclusive [65]. The efficiency type focuses on transaction cost optimization and implements activities that can improve transaction efficiency; the novel type focuses on the transaction mode and develops a new value proposition and builds new transaction mode innovation; in addition, the co-benefit business model innovation focuses on transaction participants and adopts the co-benefit value of innovation activities. Consequently, all three types of sustainable business model innovations can be presented. Then, the main and corresponding categories are shown in Tables 2–4. Extracting and comparing the original textual data show that there are potential logical relationships between the 17 independent categories identified by open coding, which requires further coding and interpretation.

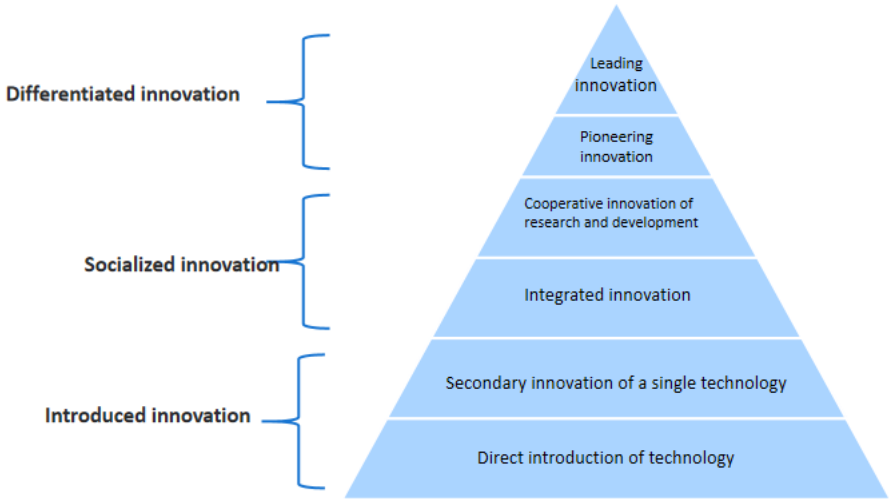


Figure 2. Subcategory hierarchy diagram of technology innovation.

Table 2. Spindle encodes: crises.

Base Category	Secondary Category	Concept	Source
Production factor crisis	Supply interruption crisis	Rapid changes in the external environment of the supply chain	1. In 2019, Huawei's component supply chain was cut off, resulting in a delayed launch of new products and more than 600 layoffs in subsidiaries. It was difficult to find alternative manufacturers in the short term for most of the high-end parts.
		Risk transmission to the supply chain enterprise	2. In 1998, Changhong adopted the channel selection distribution mode, resulting in bargaining and price system chaos among distributors, and seven large shopping malls in Jinan city jointly refused to sell Changhong products.
	Labor shortage crisis	Structural shortage of available labor	3. In 2021, the founder of Xiaomi posted a recruitment advertisement for the autonomous driving department on Weibo due to an urgent need for autonomous driving talent. Xiaomi was the first to recruit 500 technicians. Demand for autonomous driving jobs from new car companies such as Tesla, Nio, and Xiaopeng has increased yearly by more than 1.8 times.
		Labor quality and adaptability shortage	4. In 2019, Huawei released a public email to discuss why substantial numbers of their doctoral staff had left. Their cumulative turnover rate of doctoral employees in the past five years had been 21.8%. In the announcement, job mismatch was cited as the main reason why 82 doctoral employees had resigned in 2018.
Market environment crisis	Excessive competition crisis	Homogeneous competition	5. In 2014, Haier, Midea, AUX, TCL, Changhong, Chigo, and Galanz all began to intensify to the "Eleven Promotion" price war, which made it difficult for Gree to achieve its destocking target.
		Cross-border squeeze competition	6. In 2014, Apple released the Apple Watch 1 Series, and, in 2015, Huawei released its original smartwatch. In 2019, Huawei's Chinese smartwatch market share was 32.10%, compared to Apple's 12.30%.
	Customer loss crisis	Exogenous customer loss	7. During the SARS pandemic in 2003, Alibaba employees could not connect with customers offline, and their employees were infected during business trips to the Canton Fair. More than 600 employees at the Hangzhou headquarters could not attend work, which made it difficult to reduce the risk of customer loss.
		Endogenous customer loss	8. The concept of avoiding competition with China Mobile's services at all costs limited Tencent's function improvement of its QQ (instant message service). In 2007, China Mobile launched a convenient and low-cost fly letter (instant message service), and many users rejected QQ. In 2010, Xiaomi launched Mi Chat and gained tens of millions of users, threatening the QQ market.

Table 2. *Cont.*

Base Category	Secondary Category	Concept	Source
Business ethics crisis	Ethical crisis	Enterprises violate the laws and regulations	9. In 2021, employees died from the results of working excessive amounts of overtime. Pinduoduo, an e-commerce platform in China, made inappropriate comments on the matter, and employees in their Changsha offices committed suicide. Pinduoduo dismissed employees who had posted comments anonymously on the internet and remotely deleted users' photos from their cellular phones.
		The internal interests of the enterprise are inconsistent	10. The revenue structure of Sina Microblog, microblogs, have changed as they have evolved into forms of entertainment and revenue is derived from a single source. Approximately 90% of microblogs depend on advertising and marketing. Therefore, when supervision over Fanhuan marketing was relaxed, a substantial online fraud was committed which was contrary to the vision of improving the world using the power of microblogs.

Table 3. Main coding: technology innovation.

Base Category	Secondary Category	Concept	Source
Introduced innovation	Direct introduction of technology	Introduction of product technology	1. In 1991, China's air conditioning industry did not manufacture their own components. Gree did not have the technical ability to independently produce its products and imported parts in bulk for assembly to supply their air conditioners. Its annual output was fewer than 20,000 units. In 1992, Gree invested CNY 1.6 million to introduce OAK and other heat exchange equipment from the United States, which ended its history of importing heat exchange technology.
		Introduction of process technology	2. In 2013, BYD invested nearly CNY 100 million in production and equipment and introduced 24 ABB painting robots and related spraying technologies to ensure the quality of their vehicles, especially the paint finishings.
	Secondary innovation of a single technology	Imitation innovation	3. Alibaba's Taobao, a customer-to-customer shopping platform, initially imitated the double payment of eBay's online and offline, transaction technology encryption, and other technologies, and then reinvented payment methods according to China's domestic characteristics, that is, it launched a third-party payment platform known as Alipay.
		Transformation innovation	4. In 2003, based on the advantages of business-to-business technology, Alibaba evolved and expanded to a customer-to-customer mode and changed from technology introduction to transformation innovation based on the introduction and absorption of technology. Thereafter, it conducted a secondary innovation and quickly mastered the key technologies such as service-oriented architecture platforms and the cache technology of electronic payments.

Table 3. *Cont.*

Base Category	Secondary Category	Concept	Source
Socialized innovation	Integrated innovation	Enterprise resource integration	5. Huawei promotes integrated research and development; for example, the special basic platform research and development department is responsible for shelf technology, its platform, and provides technical support for product research and development. The pre-research department is responsible for the research and development of its core technology and forward-looking products, integrates the technical resources of the enterprise, and has reduced the overall research and development costs by 40%.
		Supply chain integration	6. As the leading enterprise in the supply chain, Xiaomi coordinates its information technology and integrates supply chain innovation in its manufacturing processes to coordinate its hardware, software, and service coordination, and thereby improves its value creation.
	Cooperative innovation of research and development	Leading role in cooperative innovation	7. With the industry and academic research cooperation, IFlytek has formed a multi-point layout system of independent research and development, universities and research institutions, enterprise strategic alliances, and voice cloud platform cooperation, and is always at the forefront of technology and product development.
		Equal role in cooperative innovation	8. In 2019, Baidu and China Telecom reached a 5G strategic cooperation agreement, which included 5G edge computing platform services, capability collection, and AI technology.
Differentiated innovation	Pioneering innovation	Original innovation of technology principle	9. Pinduoduo established the first decentralized online flow distribution concept and mechanism and focused on social groups as its core mode, which substantially reduced its network flow cost of e-commerce and benefited both the supply and demand side of its business. It cornered the small- and medium-sized merchant market and was spared from the consumption upgrades of mainstream e-commerce consumption. It has become one of the major players in China's e-commerce field.
		Original innovation of technological achievement	10. In 2011, when the performance of its QQ business division expanded, Tencent created a strong relationship with social software achievements by utilizing internal and crossover technology due to the strategic consideration of the entrance of the future mobile online channel, WeChat, including the distance sensor design of a voice intercom. Currently, WeChat is still the mainstream social app.
	Leading innovation	Maintaining new technology advantage	11. Sinopec had the first-mover technical advantage in the layout of hydrogen energy. In 2020, it developed hydrogen purification technology, using the by-product hydrogen as raw material, adopted the self-developed absorbent, which supported the rapid purification process, to improve the purity of its product and outperform the automotive hydrogen standard. Sinopec has invested in hydrogenation stations, hydrogen fuel cells, hydrogen storage materials, and other related fields, and is at the forefront of the industry as the largest hydrogen production enterprise in China.
		Implementing advanced technology and achieving a leading advantage	12. In 2008, China mobile started "TD-SCDMA system GPS alternative" and other technical innovations to end its dependence on GPS. It fully absorbed advanced technology in the field of mobile communication both locally and internationally. To gain an advantage over dated technology, it developed the innovative 1588v2 clock synchronization technology to replace the GPS clock transmission technology and to lead the TD-SCDMA system technology innovation and industrialization.

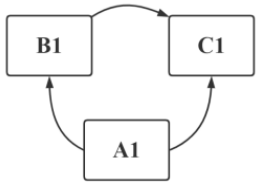
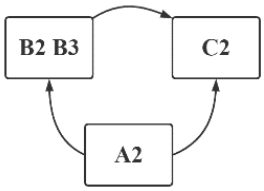
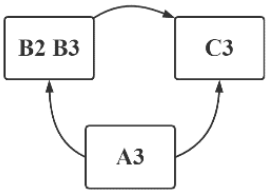
Table 4. Spindle coding: sustainable business model innovation.

Base Category	Secondary Category	Concept	Source
Efficient business model innovation	Resource allocation innovation	Capital saving	1. In 2003, due to a sudden decrease in offline customers and a squeeze on products, a loss of CNY 8 million was incurred in less than a month to JD. To end these losses and save funds, JD turned to online business, changed its original marketing and channel structure, and centrally allocated resources to develop its e-commerce capabilities.
	Integration innovation of the value chain	Labor release	2. Zto Express introduced 20 Mini Yellow vertical dart autonomous mobile robots at its Hangzhou site, which can handle approximately 2000 packages an hour, reducing the logistics system's excessive dependence on manual labor and thereby creating surplus labor resources.
		Key optimization of business innovation	3. In 2010, Sina Microblog launched the open API platform and implemented a micro-business model because of previous failures. Sina Microblog now posts in excess of 25 million posts daily and exceeds 2 billion posts annually, according to its annual report.
		Effective supply chain innovation	4. Compared to Taobao's online flow search mode, Pinduoduo's single order mode is increasingly in demand. Suppliers do not need to spend more to increase their online flow, promotions, or customer acquisition, and can still obtain a large number of stable orders, which is conducive to an optimized product structure, customized production, and creates an immediate and effective supply chain.
Novel business model innovation	Value structure innovation	Innovation in trading methods	5. By launching Taobao, Alipay, and other platform products, Alibaba's distributed e-commerce completely changed shopping and trading methods, redefined value structures and the social credit system, and had created more than 100,000 job opportunities by the first quarter of 2007.
	Value connection innovation	Business content innovation	6. Baidu has launched community products such as Baidu Post Bar, Baidu Encyclopedia, and Baidu Knower in the search field. However, it is also extensively involved in non-search fields, such as "Baidu Wallet" in the financial field, "You Ah" in the customer-to-customer e-commerce field, and is entering the online games industry while still creating new value connections and strengthening its commercial value.
		External value input	7. In 2020, NIO and CATL established Wuhan Nio-Energy Battery Asset Company to enter the new energy front-end industry to create value connections. This company became the leader in the front-end value supplement in the electricity charging market, and Nio has applied the jointly developed BaaS model to its ET5 models.
		External value extension	8. In 2021, BYD formed a strategic cooperation with the Henan government to focus on the back-end of the industrial chain to form value applications, to further strengthen the bilateral cooperation in promoting new energy vehicles, smart transportation, and other related fields, and to strengthen its coordinated development in digital transformation and other fields.
Common benefit type business model innovation	Cross-industry co-benefit	Integration of business forms	9. In 2017, the JD Health Internet Hospital was launched, which resolved the time and space constraints of medical services by providing customers with more professional online medical and health services. In addition to strictly monitoring the qualification of cooperative doctors, JD Health also trained a team of full-time doctors to ensure the quality of its online medical services.
		Benefit government and enterprise	10. In 2014, Aliyun provided technical support for the launch of Zhejiang government's service network to directly connect the government service data of provinces, cities, and counties. It is the first integrated online government service platform built in Aliyun in China and is conducive to building service-oriented governments and enterprises.
	Co-benefit environment	Low carbon strategy	11. Cnooc strictly abides by the requirements of the new Environmental Protection Law, strengthens its supervision of environmental protection and energy conservation, reduces emissions, establishes a monthly tracking and feedback mechanism, tracks and supervises 50 potential environmental hazards, achieves an energy saving of 230,000 tons of standard coal, and reduces carbon emissions from the source.

4.3. Selective Encoding

Selective coding is a deeper refinement of the main category in the previous step, and it further examines the nine main categories, finds the core categories, and develops a timeline of the impact of technological innovation solutions adopted by enterprises on business model innovation in a crisis scenario. Among them, production factors, market environment, and business ethics are the three crises in the selected enterprises. Furthermore, introduced, socialized, and differentiated technology innovations reflect the development processes, and trends of technological and business model innovations are classified as three sustainable types. Therefore, these scenarios are summarized as follows: when encountering different crisis situations, the technological innovation strategies of enterprises differ, and the elements of business model innovation also change for sustainable development (see Table 5).

Table 5. Selective coding.

Typical Relationship Structure	The Connotation of the Relationship Structure
	When encountering a production factor crisis such as a supply interruption or labor shortage, enterprises start with the introduced technology and, with the help of external technology innovation, implement the necessary value updates and logic improvements to effectively allocate the resources, integrate the value chain, and improve the efficiency of the business model.
	When the competition in the market environment intensifies and enterprises lose customers, they must search for valuable and scarce elements through differentiated or socialized innovations to enhance their competitive advantages based on heterogeneous resource endowments, realize the business path through the capture value of information and data flow, and improve the novelty of the business model.
	The new era of business ethics is more challenging. Therefore, enterprise differentiates innovative technology (e.g., big data, cloud computing, and artificial intelligence), which is at the core of the enterprise, and auxiliary social technology innovation is used to reshape its operating scenarios and patterns. Simultaneously, it adds value to the beneficial optimization relationship with stakeholders and extends the life cycle of value creation in the process of co-benefit business model innovation.

Note: A1, A2, and A3 are the production factors, market environment, and business ethics crises respectively. B1, B2, and B3 are the introduced, socialized, and differentiated technology innovations, respectively. C1, C2, and C3 are the efficient, novel, and co-benefit business model innovations, respectively.

4.4. Theoretical Saturation Test

As a qualitative research method, rooted coding emphasizes the saturation of the theory, that is, the text coding is stopped after continuous updating, and amendments when no new concepts and categories can be obtained. To ensure that the theoretical saturation of the rooted coding analysis is good, this study collected multiple datasets on the selected enterprise cases, and the results showed that there were no new concepts, categories, or relationships. Therefore, for crises, the influence of technology and business model innovations in the theoretical model has an ideal theoretical saturation.

5. Model Interpretation and Case Discovery

The first half of this article is written from practice to theory, based on rooted theory, applying a multi-case analysis method with three-level coding and analysis to extract the core and major categories from a fragmented and large set of primary data. After conducting a logical analysis and correction procedure, this study examines the impact of a crisis on technological and business model innovations. There are three paths:

First of all, in the context of the production factor crisis, enterprises usually show supply interruptions and labor shortages. In the case of resource interruption and imbalance, enterprises can properly introduce mature and new technologies to help enterprises improve production efficiency, optimize resource allocation, integrate innovation achievements and adjust the existing value chain [66], and realize efficient and sustainable business model innovation. Therefore, the first path is proposed as follows:

- Production factor crisis–introduced technology innovation–efficient business model innovation,

Secondly, in the case of market environment crisis, the crisis faced by enterprises is usually manifested as excessive competition and customer loss. The ineffective or inefficient market environment will weaken the core competitiveness and product attraction of enterprises, and it is manifested as the active or passive decline of customers' willingness to pay in the market. The time urgency and socialized technology innovation helps enterprises adjust and innovate the operation mode in the dangerous market environment, to strengthen the competitive advantage and brand image of enterprises [67], and to realize sustainable business model innovation. Therefore, the second path is as follow:

- Market environment crisis–differentiated and socialized technology innovation–novel business model innovation,

Eventually, in the context of business ethics crisis, the crisis that is confronted by enterprises is normally manifested as intellectual property infringement and customer data security threats, which greatly affect the reputation of enterprises and organizational development. Consequently, the corresponding socialized and differentiated technology improvement can preserve the corporate image to a great extent, ensure the information security of customers and the rights and interests of enterprises with technology, generate common beneficial value [68], gain mutual benefits, and make full use of crisis scenarios to achieve sustainable business model innovation. Therefore, this article proposes a third path:

- Business ethics crisis–socialized and differentiated technology innovation–co-benefit business model innovation.

The constructed theoretical model is shown in Figure 3. The second half of this article is written from theory to practice, which aims to increase the persuasiveness of the theoretical models. The model paths are explained mechanistically and supported by the case studies' descriptions. The further analysis of each path's mechanism process and corresponding case is presented in the following secondary titles, such as secondary titles from Sections 5.1–5.3.

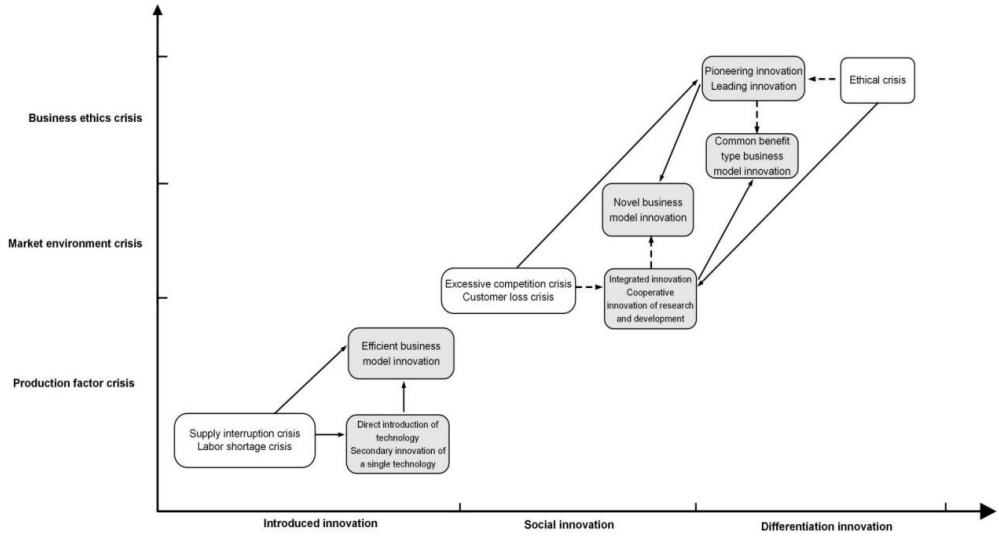


Figure 3. Illustration of crisis impact on technological and business model innovations.

5.1. Production Factor Crisis—Introduced Technology Innovation Improves Efficiency

5.1.1. Mechanism Process

Suppliers transfer risk to enterprises during information exchanges and trading. National policy restrictions, external environmental factors, or supplier quality integrity (e.g., quality, and production standards) can terminate the cooperation. In addition, a shortage of production factors such as equipment and semi-finished resources can interrupt the flow of information and logistics. Enterprises encountering supply interruption crises are less able to expand [69]. In addition, their performance depends on a series of different skills related to employees' surplus value creation which include candidates, employment, and education. If there are loopholes in the internal personnel supplement mechanism and related management, or failures in personnel recruitment and training, the personnel demands and quality will not align with the enterprise's demands, and personnel shortages will be encountered [70]. Therefore, enterprises must effectively manage production factors during a crisis; specifically, they should manage their external supplies and internal labor forces.

Supply interruptions and labor shortages occur during a crisis of production factors. Both are urgent issues which require an enterprise to reinvent many of their management systems. Most enterprises routinely deal with these crises by introducing new procedures and transforming their technical structures, that is, they directly introduce technology or apply it to a secondary innovation and so on. When enterprises first encounter a crisis, they lack technology and resource accumulations, which hinders their abilities to achieve leapfrog, socialized, and differentiated innovations. Introduced innovation can replace resources in the short term with the accumulation of technology and resources and provide timely and low-cost technical solutions throughout the crisis [71].

For example, enterprises can create innovative supply management systems or appropriately introduce mature and new technologies, such as machine learning and big data. Optimizing the critical business processes between suppliers and enterprises helps to generate behavioral models and predict risk scenarios in the production factor market, and is conducive to creating an efficient supply chain and the innovative integration of all the participants in the value chain [72].

When labor resources are insufficient to match an enterprise's market capacity planning, then an enterprise can consider, in addition to routine personnel resource practices such as outsourcing, temporary employees, and targeted recruitment, a technical solution by introducing new equipment and facilities, including robots and automation facilities. This process will allocate innovation resources oriented by efficiency and technology endowments to alleviate the labor shortage crisis by facilitating the redeployment of personnel [73]. From a cost perspective, these types of equipment and facilities have a perfect industrial chain distribution, and the financial cost of commercial introduction in the cycle is very useful in realizing the optimization of key businesses compared to the enterprise's own research. To summarize, both human resource allocations and value chain integration innovation fall within the scope of efficient business model innovation [74]. The attributes of production factor crises and technical response solutions focus on the efficiency of business model innovation. Therefore, enterprises can realize their technology endowments and crisis solutions through introduced technology innovation, and the corresponding business model innovation consists of resource allocation and value chain integration innovations.

5.1.2. Practical Case: Alibaba Introduces a Big Data Algorithm to Identify False Suppliers

Alibaba, as the largest global business-to-business platform, frequently experienced complaints of fraud in international transactions between 2009 and 2010. In February 2011, Alibaba's foreign trading platforms had received alleged fraud complaints dating back to 2009, which allegedly involved 1219 Chinese suppliers. Most of the supplier stores were specially set up as fraud portals. Although they provided high-demand products, they also attracted foreign customers with lower minimum purchase volumes, and then formed a fraud network through relatively unsafe payment transactions. This directly exposed the

problem of supplier screening, and the supplier integrity problem damaged the platform's image, resulting in Alibaba's shares falling by 8.6%.

After investigating the complaints, Alibaba first terminated its cooperation with the allegedly fraudulent suppliers and fired nearly 100 salespeople that were directly to blame. In addition, it offered CNY 1.7 million in compensation to the victims. Second, because of the supply interruption crisis, it restructured its existing technology, introduced and used algorithms concerning big data and public reviews to consolidate its merchant platforms, withdrew the related products, and improved the algorithm identification of nearly 200 fake brands and artificial processes. These procedures resulted in a substantial decline in the number of new fraud complaints. By timely optimizing its supplier-screening process in the international market, it managed to retain its international users. Finally, Alibaba joined forces with international certification institutions, such as the Tianxiang Group, to introduce the in-depth certification services of third parties to improve the accuracy of its supplier qualification certification to fundamentally eliminate fraud. Within three months, Alibaba's fraud complaint rate had dropped by 60%.

As part of the supply crisis, the obstacles of evolving from traditional e-commerce to e-commerce 2.0 is evident. Alibaba's business-to-business company has created a professional platform for global buyers and sellers, and it earns income by charging a commission and membership fees to suppliers who belong to e-commerce 1.0 mode, namely, information platform mode. Alibaba used technical cooperation and introduced technology to change its profit model from the original solution which relied solely on membership profits. To promote transaction fees, it gradually built platform and merchant-chain collaborations, helped merchants reconstruct their operating costs, reduced various operating expenses for merchants in crisis, significantly improved the platform's operational efficiency and merchant's profits, and transformed Alibaba into a service-centered e-commerce 2.0 platform.

5.2. Market Environment Crisis—Socialization and Differentiation of Technology Innovation Will Determine the New Direction

5.2.1. Mechanism Process

The market environment crisis involves excessive competition and customer loss. An excessive competition crisis occurs when the market is saturated, market shares are reduced, potential competitors cause the serious homogenization of products or services, prices are malignantly reduced, and profits are constantly weakened. Customer loss crises occur because of an enterprise's business characteristics or external environmental processes such as public health events or policy restrictions. From the perspective of economic benefits, both these crises are manifested as passive or active reductions in the market's willingness to pay. Simultaneously, the sustainable development of enterprises focuses on how to neutralize the harm caused by ineffective market environments [75]. When enterprises are threatened by something in the market environment, they usually implement differentiated technology innovation, supplemented by socialized technology innovation, to deal with the crisis and reinvent their business models.

The competitive market environment creates pressure, and the technology innovation of competitors poses a threat to enterprises' market positions. In addition, potential entrants erode market shares, which results in a loss of old customers, which intensifies the market pressures faced by enterprises. Enterprises try to maintain their competitive advantages with the help of technology innovation as a passive defense for differentiation competition and active cooperation. The leading enterprise will initialize the new consumer market through differentiated products, technology, and trading processes and realize value structure innovation, including the transaction mode and business content [76], to solve the crisis and lead the development direction of the industry. Differentiated technology innovation removes the restrictions of technology units, connects products to customers and society as a whole, forms a systematic, comprehensive, and new technology, improves

the discourse power and market share of an enterprise in the market, and fundamentally creates subtle and sustainable advantages.

Simultaneously, with the increase in market competition, product homogeneity gradually increases. Most industry products and technology have externalities; therefore, the knowledge spillover effects of industry products and technology are significant [77]. Enterprises can cooperate in innovations; however, this type of innovation does not involve a simple technology product restructuring or secondary innovation. Instead, it complies with the technology development boom, emphasizes thought defects in an enterprise's technology and business model, inputs effective external value or outputs internal value, reduces costs, achieves socialization, and improves the market payment willingness and thereby profits from this innovation.

Both differentiated and socialized technology innovations fall under systematic and comprehensive innovation and involve internal and external subjects and multi-dimensional operations, which require long-term strategies and adjustments [78]. For an enterprise, the requirement of differentiated technology innovation is more complex because it must also consider long-term development and avoid short-term behavior. The market environment crisis reveals whether an enterprise will survive. Enterprises must conduct internal assessments, create new ways of trading, reinvent their business practices, input value and external extensions, and create value structure connections to divide the market and product technology with differential and novel perspectives to become market leaders. Both value structure and connection innovations are part of the novel business model innovation [79]. Therefore, when enterprises encounter market environment crises, differentiated or socialized technology innovations determine the direction of their sustainable business model innovations.

5.2.2. Practical Case: Vipshop Opens Up the Technical Cooperation Path to Recover Customers

Competition is fundamental to maintaining market vitality. However, excessive competition, especially through homogeneous products and services, can easily cause the retreat of the pioneers despite their established advantages. Since its establishment, Vipshop was positioned as "a company doing special sales," and continued to use the keywords "special sales" in its listing and financial reports in 2012. The e-commerce platform selling genuine clothing had a repurchase rate in excess of 80%; however, its conversion rate of new users was low because of multiple competitors. Vipshop was listed in under three years; however, it encountered Taobao and other large online business platforms' containment efforts, such as clearance and brand sales. Other online business platforms were fully developed, highly subsidized, and used the fastest browsing speeds to retain new customers. Therefore, Vipshop faced stiff competition which resulted in low rates of new user conversion.

Therefore, Vipshop implemented socialized technology innovation solutions to change the network flow and benefit of the business model through cooperation in technology and networks to maintain and strengthen its business layout within the e-commerce industry. Vipshop established new transaction entities and adopted new channels to communicate with all parties, including sharing external network flows with WeChat, JD, Tencent, and the application (APP) alliances of major banks, and changed their customer acquisition strategy with the help of the high-tech technology of cooperative enterprises. Simultaneously, Vipshop developed diversified customer acquisition tools, including the WeChat mini program and intelligent marketing platforms, which accurately connected to the technical path of Tencent and ByteDance's big data, to help brands launch and obtain new customers within the efficient network of Tencent, JD, and other strategic alliances. In 2018, in excess of 20% of Vipshop's new daily customers came from Tencent and JD, and the cumulative number of visitors from the WeChat mini program reached 140 million. Vipshop not only recovered its lost customers, but also increased its financial profits yearly. In the fourth

quarter of 2020, it had increased its profits by 22%, and its net profit was 2.441 billion yuan, an annual increase of 67.7%.

5.3. Business Ethics Crisis—Socialization and Differentiation of Technology Innovation Will Reconstruct Common Benefits

5.3.1. Mechanism Process

Enterprises aim to maximize their profits, and, in this process, it is easy to ignore the performance of social and moral obligations and business ethics. The latter focuses on the compliance with the law and discipline at the enterprise level and benefits both enterprises and society. It further determines the top-level design of the business model. A business' ethics crisis refers to an employee or enterprise breaking the law or participating in socially unacceptable behavior (e.g., infringements, malicious rumors, and improper comments), which damages the enterprise's reputation, manifests as losses, creates inconsistent interests and goals, and results in decision-making mistakes and inefficient management. In recent years, many enterprises have used big data tools to identify target groups which has resulted in a business ethics crisis that affected their reputations, harmed corporate interests, and damaged the sustainable development of their businesses [80].

Furthermore, with public awareness and organizational property consciousness, intellectual property infringements will impact target customers and restrict the future innovation and development of enterprises [81]. Enterprises must form a mutually beneficial relationship with society and consumers to resolve the crisis and not blindly promote their self-interests. They should emphasize the realization of corporate interests as their fundamental goals, as well as explore solutions that can promote the sustainable development of society.

In addition, enterprises must reevaluate their interests based on the governance and management dispute, and should also consider the development of advanced technology rather than introduce simple technology to delay the spread of bad news. They can consider using 5G, artificial intelligence, cloud computing, and other cutting-edge technology to solve their dilemmas and to ensure that online customer data are safe [82]. In this crisis, improving technology is considered to be a socialized and differentiated innovation due to the expansion of the scope of social participants and the prioritizing of socialized technology innovation. Socialized and differentiated technology innovations require an in-depth consideration of the relationship between technology and people, rather than just treating technology as an auxiliary tool [83]. Furthermore, it requires enterprises to focus on common benefits to promote the core function of new technologies and rationally apply technical tools to integrate different business forms and realize the positive value creation potential of other enterprises, the government, and the social environment.

Implementing technology innovation to improve business ethics will transform an enterprise by providing a new co-benefit business model which will resolve business ethics problems by establishing a mutually beneficial relationship between the enterprise and society, realize common values, and ensure the sustainable development of the business economy and social environment.

5.3.2. Practical Case: Baidu Is Committed to a Number of Beneficial Plans to Review Its Bidding Ranking Feature

Baidu has become popular and won market recognition with its profit model innovation, namely, bidding ranking. Bidding ranking is a self-service advertising–publishing model based on networks which simplifies the reviewing and releasing of advertisements. Both advertisers and website owners benefit from the click rates and online flow. After registering and paying a deposit, either party can set their own keywords for effective publicity. When the system determines that users are searching for the same or similar words, it highlights and prioritizes the promoted content to attract the attention of users.

Although bidding ranking promoted the efficient integration and configuration of information resources, it neglected the audit mechanism. Consequently, spam and false advertising were prevalent, which annoyed users. This resulted in the 2016 "Zexi Wei

event." Initially, the event did not draw the attention of top managers, who insisted that they had implemented the system responsibly, which thus facilitated the fraud. In 2018, the negative effect of Baidu's bidding ranking was exposed by the Chinese central media, which immediately created an unprecedented ethical crisis for Baidu. Its corporate image was severely damaged, the satisfaction of users plummeted when using its search function, its stock price fell by more than 25% in the capital market, and its market value decreased by approximately 9.5 billion yuan. Baidu executives profoundly reflected on and re-examined their business model for all of their products and introduced a series of actions to rectify Baidu's advertising business. The technical aspects involved controlling the promoted content that did not account for more than 30% of the results, and the words "commercial promotion" were highlighted on the web page.

In terms of the co-benefit business model after the crisis, Baidu cooperated with the government, other enterprises, and social organizations, such as the civil affairs departments and professional institutions such as "Baby Go Home," to set up the "AI search for lost people" project. Using age-adjusted facial recognition AI technology, it had helped approximately 12,000 lost people return home within five years.

In addition, the technology of big data and deep learning had been applied to its public business since its benefit plan was released in 2019. This plan involved constructing service scenarios and provided information on public welfare institutions. It provided millions of customers and connected information on public welfare organizations to generate accurate delivery and cover different scenarios. Since its release, Baidu has promoted more than 200 public welfare organizations for free to promote social welfare. Today, Baidu provides more than 100 products and 30 targeted proposals for society and other enterprises. On the way to helping the intelligent transformation of a variety of business forms, Baidu is becoming increasingly established and is practicing social responsibility that fits it value vision.

5.4. Case Findings

Through the mechanistic interpretation of the above model and the processes of solving the crisis problem in the three case companies, it is found that the sustainable business model innovation of the companies formed by different technology innovation solutions varies in different crises. First, when Alibaba confronted a production crisis caused by a supply chain interruption due to supplier fraud, it introduced new technologies to enhance the company's business quality, thus driving the company to modify its profitability model, optimize transaction costs, and progressively develop an efficiency based business model. This case demonstrates that "production factor crisis–introduced innovation–efficient business model innovation". Secondly, when Vipshop confronted the market crisis caused by homogenization, it primarily analyzed heterogeneous technologies to promote the establishment of a new value proposition while seeking partners to attract network flow and eventually formed a unique business model. This case demonstrates the path of "market environment crisis–differentiated and socialized innovation–novel business model innovation". Finally, when Baidu confronted a business ethics crisis with a lack of ethics, it needed to apply cutting-edge technology to overhaul the company's loopholes and, most importantly, restore the company's image by sharing its existing resources and technology with consumers, society, and government, becoming a stakeholder and thus forming a co-benefit business model. This case supports the path of "Business Ethics Crisis–Socialized and Differentiated Innovation–Co-benefit Business Model Innovation".

6. Conclusions and Outlook

6.1. Study Conclusions

This study starts from the premise of how to sustainably adjust a business model through technology innovation after a crisis. It examines and discusses the mechanism of the three links using rooted coding and multi-case studies. The following conclusions are reached:

First, the literature review shows that crisis research enters the theoretical extension and application stages but lacks theoretical support for the integration of crisis and business elements and lacks a unified classification of crisis types. Second, the business model concept is diversified, and its theoretical research has low applicability in systematic and normalized crises. Finally, a systematic understanding of the evolution mechanism of crises and technological and business model innovations is lacking.

Second, 17 categories are formed and classified into three dimensions of crisis and technology and business model innovations using the rooted coding method. This determines the logical relationship of the various categories as follows: production factor crisis–introduced technology innovation–efficient business model innovation; market environment crisis–socialized and differentiated technology innovation–novel business model innovation; business ethics crisis–socialized and differentiated technology innovation–co-benefit business model innovation.

Third, after conducting a case analysis, this study finds that the production factor crisis is manifested as supply interruptions and labor shortages. Due to the urgency of these crises, enterprises must consider technology introduction for rapid value updates and maintain commercial operations to achieve effective resource allocations and value chain integrations to form an efficient business model. The market environment crisis manifests as excessive homogenized competition and customer loss. Enterprises must search for valuable and scarce technical components, enhance the competitive advantage of heterogeneous resource endowments, capture business logic through information and data flows, introduce other entities to facilitate technical cooperation, and form a novel business model. Business ethics crises are manifested as a low awareness of ethics. Big data, cloud computing, artificial intelligence, and other technologies help enterprises to reshape their operating scenarios and models by sharing co-benefit values, optimizing their relationships with consumers, the government, society, and other stakeholders and forming co-benefit business model innovations [84,85].

To sum up, this study enriches the research contents of the related fields of "the relationship between crisis, technology innovation and sustainable business model innovation". It not only defines the crisis faced by modern enterprises from a comprehensive perspective, but also comprehensively considers the four key crisis theories used to classify the crisis types and links them with the emerging concept of sustainable business model innovation, which broadens the scope of cross-field research. It has a very important theoretical contribution. In addition, in the context of the passive and single crisis response mode of modern enterprises and complex realization mechanism of sustainable business model innovation, this study systematically links crisis, technology innovation, and sustainable business model innovation. Through a multi-case analysis based on rooted theory, three paths for enterprises to realize sustainable business model innovation under different crisis scenarios are obtained, providing positive solutions for enterprises to cope with and transform crises. It is of great practical significance to provide practical references with high applicability and that can effectively demonstrate sustainable business model innovation.

6.2. Countermeasures and Suggestions

This study summarizes the crises encountered by enterprises and emphasizes the adaptability between the theory and practice of crises and technology and business model innovations, from which most enterprises can obtain technical solutions for specific crises and directional guidance for their sustainable business model innovations. The specific countermeasures are as follows:

First, enterprises must have a strong awareness of the crisis and implement crisis response and management systems because crises are an ever-present danger. Enterprises' technology strategies should be embedded in the consciousness of crisis normalization and in the business model architecture, which provides scope for a significant change in crisis management intervention.

Second, when choosing how to deal with crises, enterprises must always use technology innovation because it is a powerful way to adjust business operations. First, when enterprises encounter supply interruptions and labor shortages during a production factor crisis, innovation in technology introduction is the most cost-effective, whereas the production factors are no longer scarce factors in the efficient business model innovation. Second, when enterprises encounter homogeneous products or cross-border market competition, they should create pioneering products and technology through differentiated innovation in products, and socialized innovation in technical cooperation, to enhance the novel business model innovation. Third, when encountering a business ethics crisis, enterprises must fully use their own existing technology and resources and also those of society and the environment through socialized technology innovation, which facilitates the benefiting of both parties from a harmonious relationship, to build a co-benefit business model innovation.

Finally, the complex characteristics of crises result in innovation creating a variety of logical links between technology and sustainable business models. Therefore, it is difficult to determine the most appropriate technology innovation scheme because of enterprises' heterogeneities. Therefore, enterprises should comprehensively consider their own characteristics, the crisis type, and many other factors to coordinate their technical and sustainable business model innovations.

6.3. Limitations and Future Research

First, although the research method improves the credibility of the conclusions, the original data collected from official websites, journals, and social media platforms are second-hand data, and therefore there are inevitable problems such as data errors and incomplete collections. Therefore, future studies can obtain first-hand data using interviews and questionnaires to ensure the reliability and timeliness of data.

Second, enterprises for the case studies are selected from multiple industries, including the secondary and tertiary industries, though mainly from the tertiary industry. In the future, the scope of selected enterprises can be expanded, and general research can be conducted on enterprises with emerging new business forms without ignoring traditional enterprises.

Third, this study examines the relationships in most cases, which may not cover other crisis types such as technology innovation. It also differs from the flexible crisis response mechanism in the real business world. Future studies can consider other types, more logical links, and improve the overall scenario of enterprise technology and sustainable business model innovations during crises.

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