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The Influencing Factors of Enterprise Sustainable Innovation: An Empirical Study

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Abstract: Sustainable innovation is the inexhaustible source of development of enterprises. Within fierce market competition, only by depending on continuous innovation can an enterprise exist and develop. By conducting an exploratory factor analysis and a confirmatory factor analysis, this paper proposes a theoretical model, dividing enterprise sustainable innovation ability into three aspects: knowledge innovation capability, production innovation capability, and market innovation capability, and analyzes the influencing factors respectively. Finally, applying this theoretical model to a practical case, with system dynamics method, the simulation results show that they are consistent with real enterprise facts. Therefore, the framework of determinants of sustainable innovation built in this paper has already been verified theoretically and practically. It not only lays a theoretical foundation for further research, but also provides a clear ground for firms to improve their sustainable innovation.

Keywords: sustainability; innovation; influence factor; system dynamics

1. Introduction

In today's society, sustainable innovation has been the basic goal of enterprises [1]. Most scholars agree that enterprises can continuously implement innovation, and they believe that any enterprise can successfully do it. However, because innovation has high risks and needs great input, some enterprises are unwilling to undertake innovation for fear of the risks. Geus [2] elaborated the view that if enterprises can improve their adaptation to the external environment and strengthen their competitiveness, they can exist and develop in fierce competition. Ichak [3] proposed an enterprise life cycle theory. He explained that, like other organic creatures, enterprises have a life cycle as well. He pointed out that enterprises can keep sustainable development and extend their existence in the market. Enterprises should constantly work to make themselves energetic and work here indicates innovation.

Since the proposal of innovation theory [4], by persistent studies and numerous practices, scholars and practitioners highly agree that the only tip for enterprises to make continuous profits is innovation. Sustainable innovation can make enterprises' profits keep growing. Continuous innovation activities contribute to promoting the continuous increase of enterprise economic benefits and continuous development of enterprises. The very basic motive and single path for enterprises to achieve sustainable development is sustainable innovation [5]. The father of competitive strategy, Porter, noted that the business environment of enterprises was changeable and hard to control [6]. Only depending on traditional activities such as streamlining the organization, reducing cost, or restructuring process can it possibly guarantee the long-term existence of enterprises. Only by continuously implementing innovation can enterprises build their competitive advantages in the long run and be adaptive to changes in both internal and external environment. Therefore, sustainable innovation is the only way for enterprises to exist and develop.

In 1997, the prominent management consultancy company Arthur D. Little conducted a global survey on "business innovation". Results showed that if enterprises wanted to make breaking through and obtain the lead in the fierce competition, the basic way was to implement active and positive sustainable innovation. Sustainable innovation is the fundamental task of enterprises if they wish to exist in an unstable environment. It requires frequent policy surveillances, technologies, and even the capabilities to adapt to fast changes [7]. With the growth of customers' needs and the fast development of information communication technologies (ICT), enterprises face very fierce competition in terms of globalization, customization, and service transformation. The importance of sustainable innovation is more and more evident, particularly for enterprises' sustainable existence, customer satisfaction, and technology improvement [8]. Sustainable innovation is the golden rule for organizations to survive in the competitive environment. Sustainable improvement and innovation are very essential for organizations to survive [9]. To maintain competitive advantages, enterprises should continuously improve the process and products, establish their innovation capability, and dynamically support their strategic business [10]. Hence, it is well acknowledged that sustainable innovation is the indispensable requirement of innovative enterprises in their sustainable development.

Sustainable innovation is important, but there is no consensus on the determinants of sustainable innovation which brings trouble for further studies. What is more, even the definition of sustainable innovation is often confused with that of technological innovation. Most empirical studies only built a theoretical framework and have not provided practical verification [7–10]. There lack cases to support the empirical results. In this paper, we use an empirical method to provide evidence about the determinants of sustainable innovation and then test these factors by a particular case.

2. Literature Review

The connotation and characteristics of sustainable innovation. Enterprise sustainable innovation refers to the process of which, within a long period, an enterprise constantly launches and implements new projects and continuously obtains the innovative benefits [11]. The sustainable innovation of enterprises has three basic characteristics [5]:

(1) Persistence. The sustainable innovation is a process. It has a time duration.
(2) Sustainable economic growth. The innovation theory tells us that innovation should bring economic benefits. Similarly, sustainable innovation should bring the continual growth of economic benefits.
(3) Sustainable development of enterprises. According to Schumpeter's view [4], innovation means development. Therefore, sustainable innovation should lead to the continual improvement of an enterprise's economic power, technological power, and business scale.

The successful sustainable innovation process is not a simple aggregate of many innovative programs in a time sequence but complex and non-linear process comprised of many innovative programs and a system of innovative program clusters [12].

Factors that influence enterprise sustainable innovation. Individual capability is a complex integration of an employee's knowledge, skills, and capability. They are quite essential for the effective and efficient operation of an enterprise. When an enterprise is pursuing the implementation of strategies and sustainable innovation, the process lies in people in the organization. Employee participation means employees participate in the process of formulating and implementing the management decisions. They communicate with managers and further influence the management process of enterprises. In the process of enterprise sustainable innovation, the capability of employees and the degree of participation can influence the organization's sustainable innovation behaviors and therefore influence the organization's innovation performance. The active participation of employees is the powerful guarantee of an enterprise's innovation activities. Many studies show that some individual capabilities, such as the learning capability, effective communication capability, creative capability, and team cooperation capability can strengthen the collective behaviors and organizational capability which is very important for sustainable innovation [13–15].

From the above analysis, we can find that the studies on sustainable innovation theory have gained abundant achievements, carried out many of meaningful dytudies, and published many high standard papers. However, there are still some gaps that remain to be filled.

(1) Scholars have defined sustainable innovation from different aspects. They have different focuses and each has its advantages. However, until now there is no consensus on what is sustainable innovation, and most definitions have not clearly shown the nature of sustainable innovation. For example, it has not emphasized such characteristics of sustainable innovation as persistence, dynamics, and human orientation. Sustainable innovation is an ongoing innovation. It is not transient and occasional innovation [5]. We should focus on the persistence of sustainable innovation. Sustainable innovation is a fundamental task of organizations in a dynamic and unstable environment. We also should pay attention to the dynamic nature of sustainable innovation. In terms of sustainable innovation, the knowledge of employees is the most important resource for enterprises [16]. Their innovative behaviors and learning activities are keys for the sustainable innovation of an organization. Hence, the definition of sustainable innovation should focus attention on the subject of innovation. Any activity that serves a certain purpose. The continuous increase of enterprises' economic benefits comes from sustainable innovation behaviors. The sustainable development of enterprises also depends on sustainable innovation. However, how the motivation of knowledgable workers' innovative behaviors can influence sustainable innovation is hardly discussed in the previous literatures.
(2) Some scholars have not differentiated the sustainable innovation capability from the technological innovation capability. Technological innovation refers to development of new technology or the application of innovation to the present technology. In fact, technological innovation capability is part of sustainable innovation capability. By analyzing the preceding literature [12–15], we propose that sustainable innovation capability is a synthesized capability. It is an innovation system, which is composed of all kinds of innovation capabilities. Through the interaction of all kinds of innovation capabilities, it can improve the enterprises' sustainable innovation capability and promote the sustainable development of enterprises. Generally speaking, sustainable innovation capability should incorporate sustainable technological innovation capability, production innovation capability which applies new technologies to practice, and market innovation capability which can turn the new products and new services into enterprise profits.
(3) Scholars mainly synthesize the literature review and empirical analysis to examine the factors influencing sustainable innovation, but the empirical sample is relatively quite small. There is also a lack of practical cases to test the results of these empirical studies.

The methodology adopted in this paper is as follows: firstly, based on literature review, the hypotheses are proposed; secondly, based on interviews and previous scales, the questionnaires are designed; thirdly, by collecting data through questionnaires and fitting the model based on the data collected, the theoretical model is tested; finally taking an enterprise in practice as case, the appropriateness of the theoretical model is verified.

3. Empirical Analysis of the Influencing Factors of Enterprise Sustainable Innovation

3.1. Hypotheses and Model

In recent years, respectively from theoretical and practical angles, many scholars studied the influence of knowledge management and knowledge learning on sustainable innovation. Cole [17] pointed out that the core of sustainable innovation is exploration and learning. The persistent learning mechanism is an institutional guarantee for enterprises to realize effective knowledge accumulation and successful sustainable innovation. From continuous learning to sustainable innovation to continuous development is the realization model for an enterprise's persistent development. Boer *et al.* [18]

designed a CIMA model. It adopted several related variables to elaborate the continuous learning process. The CIMA model is designed to be used by researchers acting as facilitators to help companies in fostering and sustaining the process of learning and knowledge management. CIMA provides a structured, step-by-step approach to mapping the user company's current level of learning, identifying strengths and weaknesses and then suggesting enabling mechanisms which can be implemented by the company to stimulate continuous improvement and learning, depending on specific contingencies. This process is supported by a behavioral model, explaining relationships between learning behaviors and outcomes, capacities enabling these behaviors, levers that managers can use to change existing or promote new behaviors, and contingencies affecting this entire set of relationships. Based on the systematic view, Xu [19] applied the KM (knowledge management) transformation model to explain how knowledge management contributes to promoting the value creation and supporting sustainable innovation. KM includes a meta-model and a macro process, a life cycle of knowledge is created based on the meta-model. A macro process of KM is built on the knowledge life cycle from the perspective of KM. Aiming to improve the core competitiveness, organizational learning is the action that focuses on information and knowledge techniques. It is a process to transform or adapt to the continuously changing environment. Many empirical studies show that organizational learning can exercise positive influence on innovation performance by innovative behaviors [20–23].

3.1.1. The Constitution of Sustainable Innovation Capability

Sustainable innovation capability is the capability of an enterprise to persistently and innovatively combine all kinds of elements (that is, human resources, materials, and knowledge), dynamically obtain the continuously sustainable competitive advantages, and continuously realize economic benefits [24]. Zhidong Li [25] held the view that sustainable innovation capability is the capability to persistently and innovatively synthesize all production factors (including human resources, financial resources, and material resources) to obtain sustainable competitive advantages and finally obtain potential profits. It is mainly comprised of the knowledge innovation capability, production innovation capability, and market innovation capability.

3.1.2. The Sustainable Innovation Indicator System

Some studies on sustainable innovation capability mainly focus on the indicator system of sustainable technological innovation capability [26]. There is no uniform standard for the construction of the indicator system of enterprise sustainable innovation capability. Major studies are built on scholars' personal understandings on enterprise sustainable innovation. Some scholars thought sustainable innovation was a dynamic process that incorporates interrelated stages [27]. They focus on dividing the stages of sustainable innovation process and separately evaluating the capability of each stage. The scholars holding the process view usually used the input capability, production capability, marketing capability, and output capability indicators as the core indicators to evaluate sustainable innovation capability [28–30]. Based on the composition of sustainable innovation, some scholars carried out a studies on sustainable innovation capability. They held that sustainable innovation capability is a systematic concept with human characteristics and a hierarchy of multiple factors [31].

Knowledge is a key foundation for sustainable innovation [32]. Schumpeter thought that the basic reason for the development of capitalism is innovation, not capital or labor [33]. In the innovation process, the most important thing is production, propagation, and the use of knowledge and information [34]. Drucker [35] pointed out that knowledge is the most important economic resource of future society. Innovation is the process and result of knowledge application. Therefore, enterprises place great emphasis on knowledge resources. By knowledge acquisition, integration, and application, we can achieve satisfactory economic and social performance and achieve sustainable innovation. In this paper, knowledge acquisition is interpreted as knowledge innovation capability. The integration and application of knowledge are interpreted as production innovation capability. Economic and social performance is interpreted as market innovation capability.

There are also scholars who discussed the influencing factors of sustainable innovation from a sustainable innovation motive perspective [36]. They held that it was the innovation benefits that led to the persistent pursuit of enterprises for continuous increase in profits and continuous development. This formed the fundamental driving force for sustainable innovation. Knowledge innovation can bring Schumpter rent and hence excess profits [34]. Production innovation can lead to reduction in cost and enlargement of production capacity. It can bring profits due to lower marginal production costs compared with rivals. Consequently, it can bring more Ricardian rent and Chamberlinian rent [37]. Market innovation also can bring continuous and stable economic benefits for enterprises by creatively selling products and services [32].

For these studies, they usually use knowledge sustainable innovation capability, production sustainable innovation capability, and market sustainable innovation capability as main evaluation indicators [38–41].

3.1.3. The Influence of Incentive Mechanisms on Sustainable Innovation

Innovation is obtained by the combination of different ideas, cognition, information processing, and evaluation methods [42]. Knowledgable employees play an expert role in their department and become the best sources for organizations to create new ideas and knowledge [43]. They can increase the benefits of customers and reduce production and service shipping costs. In this way, they improve the organizational performance. If enterprises want to successfully promote the organizational innovation, they need to know how to utilize the incentive policies and strategies to help all employees to participate and fully realize their potential [44]. Incentive mechanism refers to a particular method or management system, which maximizes employees' commitment to organizations or work. Empirical studies also showed that the motivation of knowledgable workers such as rewards, recognition, work freedom, cooperative team, work challenge and pressure [45], cooperative trust, participation in decision, compensation, and broad career path [46], the goal-oriented compensation system, and way a team is organized can positively influence innovation performance [27].

3.1.4. The Influence of Knowledge on Sustainable Innovation

The knowledge that enterprises have and the continuity and speed of enterprises to acquire the knowledge they need are key for enterprises to obtain and maintain sustainable innovation [47]. Relying on knowledge acquisition, not only the knowledge demand of enterprises can obtain new knowledge but also the managers and member enterprises can study, experiment, and utilize new knowledge and finally produce performance [48]. Knowledge acquisition includes the knowledge learning capability and knowledge creation capability. Knowledge innovation is the first stage. Enterprises need to comprehensively use new knowledge from both internal and external environments to solve the problems of enterprises [49]. We need to continuously turn intelligent capital into innovation outcomes [50]. If knowledge cannot be transferred, then knowledge acquisition will lose its meaning. Therefore, the knowledge transferring capability and the innovation performance of enterprises are important influencing factors of enterprise sustainable innovation capability [51]. Only when we transfer and apply the knowledge to where it is needed can we effectively solve the practical problems and the value of knowledge can be fully embodied [52]. Based on the above analysis and the literature review, we find there are quite a lot of factors which can influence innovative capability and their relations are complex. However, by describing the variability among observed, correlated variables, factor analysis can integrate these variables into very few factors and present the relationship between the original variables, the observed variables and the factors, and the unobserved variables. It is an approach adopted to test how the latent structure influences the observed variables [53].

We constructed the research model and propose the following hypotheses (shown in Figure 1.):

Hypothesis H1A: Knowledge learning capability has a positive effect on knowledge innovation capability;

Hypothesis H1B: Knowledge creation capability has a positive effect on knowledge innovation capability;

Hypothesis H1C: Knowledge transferring capability has a positive effect on knowledge innovation capability;

Hypothesis H1D: Profit-making capability has a positive effect on knowledge innovation capability;

Hypothesis H2A: Knowledge learning capability has a positive effect on production innovation capability;

Hypothesis H2B: Knowledge creation capability has a positive effect on production innovation capability;

Hypothesis H2C: Knowledge transferring capability has a positive effect on production innovation capability;

Hypothesis H2D: Production equipment level has a positive effect on production innovation capability;

Hypothesis H3A: Profit-making capability has a positive effect on market innovation capability;

Hypothesis H3B: Marketing capability has a positive effect on market innovation capability.

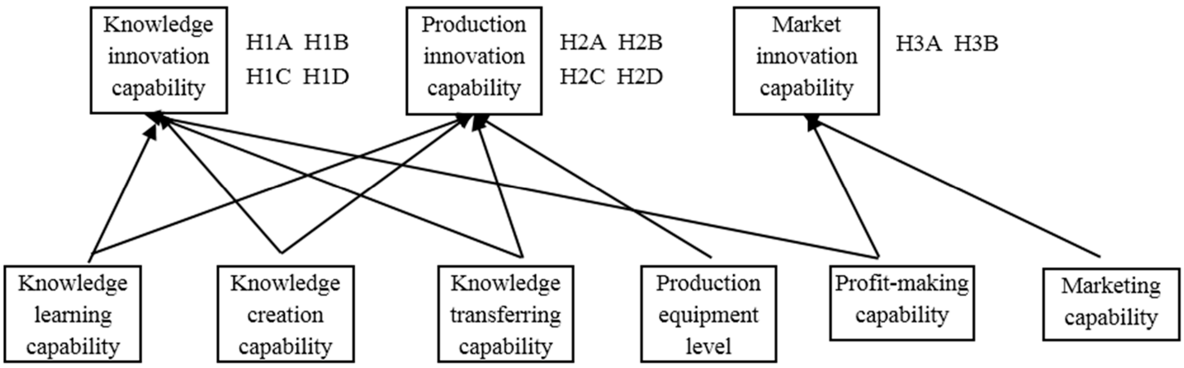

Figure 1. Hypotheses framework.

3.2. Questionnaire Design and Data Sources

To ensure the validity and reliability of the measurement tools, in the process of designing questionnaires, the author has adopted literature analysis, enterprise investigation, and expert interviews to implement the study. Firstly, we designed preliminary questionnaires based on literature analysis. Most of the items are coming from the mature scales [54–63]. We also complemented and revised these items; secondly, we implemented a consultation for the questionnaires. We invited a chief marketing officer, a chief information officer, and a chief operation officer respectively from three listed companies from the Jiangxi province in China to fill and discuss the questionnaires. They were asked to evaluate the designs of the items as well as the appropriateness of words. Then we evaluated the appropriateness of these items; finally, based on the opinions of experts, we adjusted and revised these questionnaires to get the final version of the questionnaires. The questionnaire is shown in Appendix A. The formal questionnaires include seven latent variables and 18 items. All the items use Likert five-point scales.

This study uses questionnaires to gather data. The sample mainly comes from Jiangxi province. Others are drawn from Guangdong province, Jiangsu province, and Zhejiang province. The selection of enterprises is mainly based on the following conditions: (1) the enterprise should be established no less than 10 years; (2) the enterprise should continuously implement innovation for a long period (at least 10 years); (3) the economic benefits have kept increasing for a long period (at least 10 years); (4) the investigation subjects are CEOs, top managers, R&D directors, production directors, sales directors. Depending on the above criterion, we chose the enterprises in the innovative enterprise list. From March to August 2015, we have sent 500 questionnaires and received 425 questionnaires back. The receiving rate is 65%. Considering the completeness of data, we chose 321 questionnaires finally. There were a total of 321 people to be interviewed, where there were 13 CEOs, 32 top managers, 121 R&D directors, 76 production directors, 79 sales directors. There were seven people without a bachelor's degree, 239 people with a bachelor's degree, and 75 people with master's and doctorate degrees. Within the enterprises surveyed, there were 132 enterprises in the manufacturing industry, 101 enterprises in commercial industry, and 88 enterprises in the service industry. 24% of the completed questionnaires were collected through face to face interviews and 76% were collected through internet tools (including QQ, Wechat, Email). Questionnaire item design and their sources are shown in Table 1.

Table 1. Questionnaire item design and its source.

Variable	Definition	Question	Source
Knowledge learning capability	Capability to acquire general knowledge	4	[54,55]
Knowledge creation capability	Unique knowledge creation capability	3	[56]
Knowledge transferring capability	Capability to transfer knowledge into new products and services	3	[57,58]
Production equipment level	Degree of advancement of production equipment	1	[58]
Profit-making capability	Revenues of new products and services	2	[59,60]
Marketing capability	Quality of market network and marketing employees	2	[61,62]
sustainable innovation capability	including knowledge innovation capability, production innovation capability, and market innovation capability	3	[57,63]

3.3. Data Analysis

3.3.1. Reliability Analysis

This study uses Cronbach's Alpha coefficient to test the reliability of each variable. See Table 2. The Cronbach's Alpha coefficient of each variable is between 0.789 and 0.912. All are larger than 0.7, which is within the acceptable range. It shows the questionnaires have relatively high reliability. As shown in Table 2.

Table 2. Reliability analysis of measurement variables.

Variable	Question	Cronbach's Alpha
Knowledge learning capability	4	0.789
Knowledge creation capability	3	0.892
Knowledge transferring capability	3	0.837
Production equipment level	1	0.912
Profit-making capability	2	0.893
Marketing capability	2	0.821
Sustainable innovation capability	3	0.792

3.3.2. Validity Analysis

Validity refers to the effectiveness and correctness of questionnaires, namely, the degree of the questionnaires to measure the characteristics of the variables. It is a major criterion to measure the quality of questionnaires. The items of the questionnaires mainly come from the current literature. Many scholars have applied these scales to measure variables [54–63]. A small part of them is designed based on literature analysis and measurement purpose. All these questionnaires are revised based on experts' opinion. Therefore, these questionnaires have a relatively high content validity.

The construct validity is about testing whether the items can measure the variables. We usually use factor analysis to test the structure of the questionnaires. The core indicators are KMO measure and Bartlett's test. If the value of KMO is 0.7, it indicates the construct validity is good. If the value of KMO is 0.8 or bigger than 0.8, then it means excellence in construct validity. The indicators are mainly KMO sample test and Barlett ball test. As shown in Table 3.

Table 3. Validity analysis of measurement variables.

Variable	KMO	Bartlett Chi-Square	Sig
Knowledge learning capability	0.860	802.841	0.000
Knowledge creation capability	0.853	368.844	0.000
Knowledge transferring capability	0.726	179.544	0.000
Production equipment level	0.884	742.240	0.000
Profit-making capability	0.865	772.880	0.000
Marketing capability	0.881	703.208	0.000
Sustainable innovation capability	0.909	1036.371	0.000

From above analysis, we can see that KMO value of each latent variable is bigger than 0.7 and its p value is 0; the value of Bartlett's test is relatively big, which also shows the construct validity is good. Considering the analysis of both content validity and construct validity, we can conclude that the indicators and questionnaires of this paper have high validity.

3.3.3. Testing of the Theoretical Model

The above analysis shows that the reliability and validity of the variables in this study are all acceptable [53]. Therefore, we can use the structural equation model to analyze. Through AMOS 18.0 analysis, we can get a series of results. In terms of the evaluation of model fit, there are four types of indices: Chi square test, residual analysis, fitness index, and index of substitution. As shown in Table 4.

Table 4. Indicator of model fit.

Indicator		Value	Receive Standard	Judgment
Chi square test	CMIN	0.08	>0.05	Accepted
	CMINDF	1.332	<2	Accepted
Residual analysis	RMR	0.17	The smaller the better	Accepted
Fitness index	GFI	0.97	>0.85	Accepted
	AGFI	0.93	>0.90	Accepted
	PGFI	0.74	>0.50	Accepted
	NFI	0.96	>0.90	Accepted
	IFI	0.97	>0.90	Accepted
Substitution	CFI	0.967	>0.90	Accepted
	RMSEA	0.094	The smaller the better	Accepted
	IFI	0.945	>0.90	Accepted

Taking all the indicators into consideration, the overall fitness of this study is good. Because a structural equation can not only consider and process multi dependent variables and evaluate the factor structure and factor relations, but it also can evaluate the fitness of the whole model and tolerate certain measure errors, it can satisfy the requirements of this study [64]. Therefore, we can use the results of the model to test these hypotheses. The path coefficients of the model and the results of the hypotheses test can be seen in Table 5.

According to the statistic analysis, we get the path coefficients of the model and the results of hypotheses test. From the results, we find out hypotheses H1A, H1B, H2C, H2D, H3A, and H3B are supported while hypotheses H1C, H1D, H2A, H2B, are not supported.

Table 5. The path coefficient of theoretical model and the test of hypotheses.

Hypothesis	Coefficient	*p*	Test Results	Hypothesis	Coefficient	*p*	Test Results
H1A	0.65	0.000	Support	H2B	0.81	0.451	Deny
H1B	0.57	0.002	Support	H2C	0.37	0.001	Support
H1C	0.18	0.576	Deny	H2D	0.55	0.000	Support
H1D	0.19	0.612	Deny	H3A	0.81	0.000	Support
H2A	0.27	0.607	Deny	H3B	0.77	0.000	Support

Therefore, we get the revised theoretical model, as shown in Figure 2:

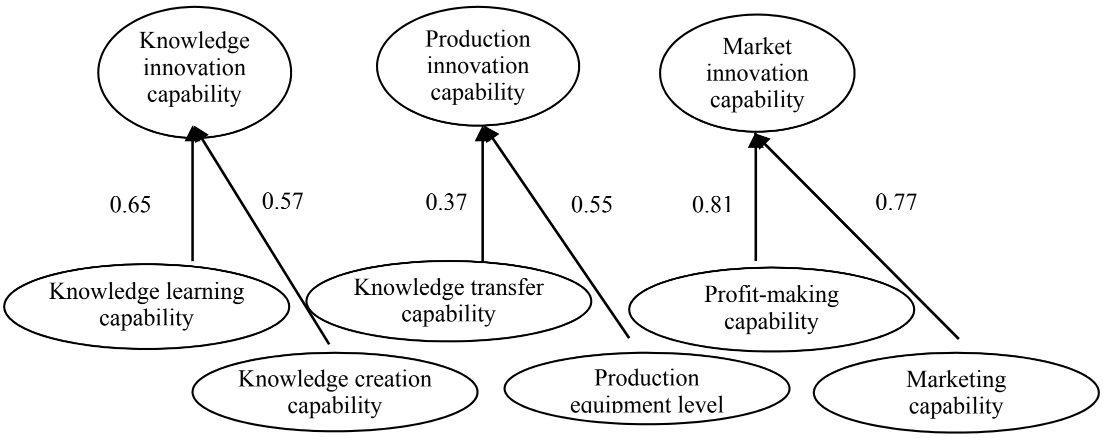

Figure 2. The revised theoretical model.

4. Case Analysis of the Influencing Factors of Sustainable Innovation

We use the Jiangling Motors Co., Ltd. (Nanchang, China) as example. Based on the above analysis, we apply the system dynamics model to test the effectiveness of the sustainable innovation model.

4.1. Brief Introduction

Jiangling Motors Co., Ltd. (JMC in abbreviation hereinafter), was established in 1968 and went public in 1993. It is a key player in China's automotive industry with commercial vehicles as its core competitiveness, has been ranked as one of China's Top 100 Listed Companies for consecutive years. In 2014, JMC hit record highs in its business indexes with sales revenue reaching 25.5 billion RMB and a volume of over 276,000 units. Currently, there are 14,036 people in the company. JMC meets with our requirements for sustainable innovation enterprise.

JMC is a large auto listed company and also known as innovative product producer. The first Sino-foreign jointly developed car was produced jointly by JMC and Ford Company. JMC has built an advanced global digital design platform and simultaneously developed and released new products with Ford Company. In recent years, it introduces new cars almost each year. What is more, JMC has built a JPS lean production system and established a quality management information system. The Transit models with their excellent quality have won the Ford Global Customer Satisfaction Gold Award for three consecutive years and was named China's Best Commercial Vehicle. In addition, JMC has established a big marketing network covering the whole of China. It has more than 800 dealers. Its overseas distribution service network develops very quickly and its overseas sales keep increasing. Now it is a major exporter of diesel light commercial vehicles in China. Considering the above information, and JMC's excellent knowledge innovation capability, production innovation capability, and market innovation capability, this study chose JMC as the typical case to implement the system dynamics analysis.

4.2. System Boundary and the Construction of Stock and Flow Diagrams

System dynamics (SD) method is a quantitative methodology built on the basis of feedback control theory, using computer simulation technology as a tool and it is good at studying the complex social and economic system [65]. This method is more suitable for solving less complex social and economic problems and the hardly quantified problems with inadequate data in particular. Based on the causal relationship of elements in a SD model, limited data, and a certain structure, problems can be deduced and analyzed. Therefore, SD is one of the main methods to study a complex system. Based on the analysis of the theoretical model in the above section, this paper analyzes the sustainable innovation capability of a company. However, the relationships within an enterprise are complicated and can be regarded as a complex system. In addition, the data acquisition of many variables is subjective and many elements are hard to quantify. Considering these restrictions, SD provides an angle to study the research issues systematically and objectively.

This paper establishes a system dynamics model for JMC. The main purpose is to analyze the interactions within the internal elements in JMC and forecast the sustainable innovation tendency of JMC. The main goal is to test the theoretical model proposed in the above section and analyze the effect of different factors on enterprise sustainable innovation. By analyzing the simulation result, we can provide references for policy design. The system boundary of the model system is JMC, the time boundary of the model system is 2005–2020. The historical data is 2005–2014.

The above theoretical model has described the relationship between the variables. It has defined the positive effect one variable may have on another variable. However, except for such relationships, we need to know the quantitative relationship and how the variables try to change with time. We use the system dynamics tool to describe it. The stock and flow diagram introduces the stock variable (LEV(t)) and flow variable (RAT(t)) and defines the variable equation. It uses a quantitative way to describe the system and can observe the evolutionary results of the system with the development of time.

Usually, in a stock and flow diagram there are several pairs of stock and flow variables and it is common that each flow variable is related to several stock variables. In view of such complicated relationship among stock and flow variables, we use the rate variable fundamental in-tree modeling method to simplify the system structure [66].

According to this method, based on the above stock and flow diagram, we can construct a series of rate variable fundamental in-tree models, the structure is shown in Figures 3–6. Based on the theoretical model verified empirically in Section 3, we decompose sustainable innovation capability into knowledge innovation capability, production innovation capability, and market innovation capability (see Figure 3). We decompose knowledge innovation capability into knowledge learning capability and knowledge creation capability (see Figure 4). We decompose production innovation capability into equipment level and knowledge transferring capability (see Figure 5). We decompose market innovation capability into profit-making capability and marketing capability (see Figure 6). Based on the literature descriptions [54–63] in Table 1, we use four questions to measure knowledge learning capability, where three of them aim at knowledge collecting capability and one for R&D employee capability. We use three questions to measure knowledge creation capability, one for the number of patents, one for the expenditure input, and one for risk factors. We use one question to measure equipment level. We use three questions to measure knowledge transferring capability, one for the number of brands, one for transferring risks, and one for capability of the production of knowledge employees. We use two questions to measure profit-making capability, one for profit increase, and one for sales revenue of new products. We use two questions to measure marketing capability, one for marketing network, and one for marketing employee capability.

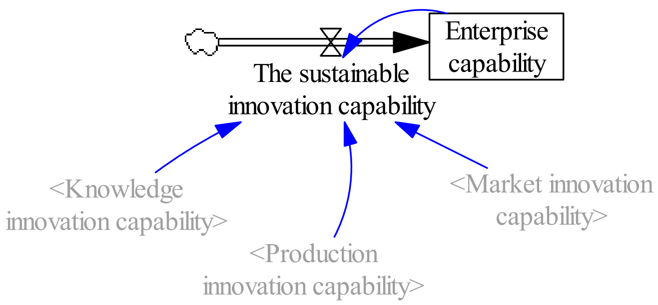

Figure 3. The fundamental in-tree model of sustainable innovation capability.

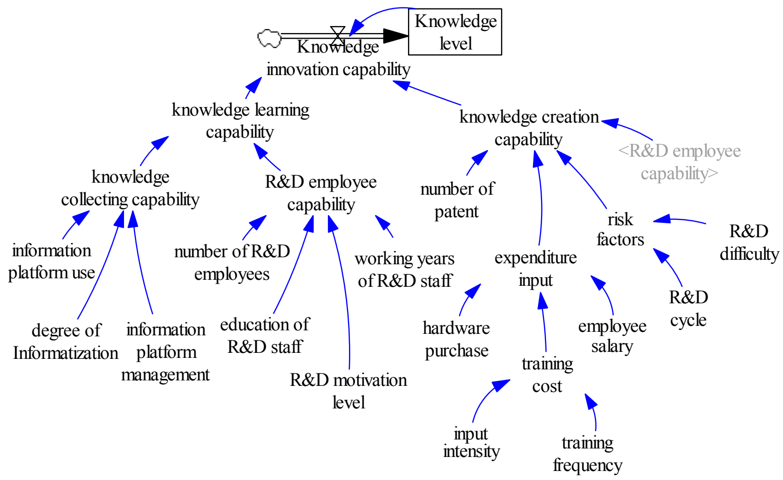

Figure 4. The fundamental in-tree model of knowledge innovation capability.

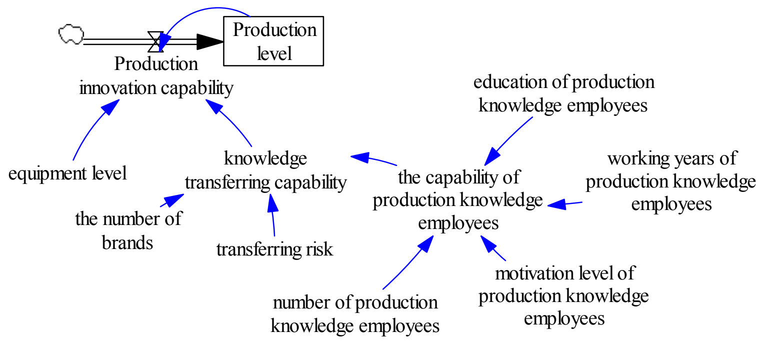

Figure 5. The fundamental in-tree model of production innovation capability.

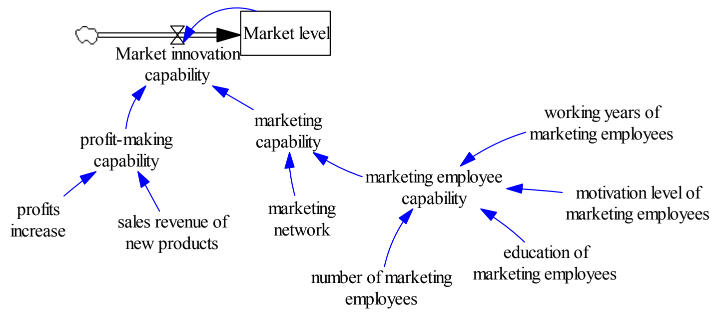

Figure 6. The fundamental in-tree model of market innovation capability.

In Section 3.1.2 this paper has analyzed the sustainable innovation indicator system. In particular literature [26–32] have put forward the constituents of sustainable innovation and designed measures of sustainable innovation. Based on the above literature review, especially the views of literature [29–31], we further decompose the three innovation capabilities and form the leaf node so that they can be measured and can be simulated by system dynamics. The simulation data are partly drawn from the historical data of JMC Company. Because some leaf nodes cannot be quantified, we acquire the data from the questionnaires designed in Section 3. Considering the staff of JMC know JMC best, the questionnaires are filled yearly by directors of JMC responsible for R&D, production, and marketing. The average points of the three people are the final value of the item. Where the motivation level of employees refers to the economic motivation, which has not considered other forms of motivation and its value is equal to the annual bonuses divide the monthly salary; The working years of employees refers to the working years of the employee at JMC; Education of employees is measured by their diploma and Appendix B provides the calculation formula; R&D cycle refers to the average length of R&D programs before the calculating year and we use years as the unit; Transferring risk refers to R&D techniques to divide the techniques used practically; Hardware purchases uses 10,000 yuan as a unit; Table 6 shows the data source of each leaf node. In the table, Questionnaires are denoted by Q, and Q. No. 1 denotes the first question of questionnaire and so on. The historical data of JMC is abbreviated as J.H.D.

Table 6. The data source of SD.

Item	Source	Item	Source
Degree of informatization	Q. No.1	Input intensity	Q. No.6
Information platform use	Q. No.2	Training frequency	J.H.D.
Information platform management	Q. No.3	Employee salary	J.H.D.
Number of R&D employees	J.H.D.	R&D cycle	J.H.D.
Education of R&D staff	J.H.D.	R&D difficulty	Q. No.7
R&D motivation level	J.H.D.	Equipment level	Q. No.8
Working years of R&D staff	J.H.D.	Number of brands	J.H.D.
Number of patents	J.H.D.	Transferring risk	J.H.D.
Hardware purchases	J.H.D.	Sales revenue of new products	J.H.D.
Number of production knowledge employees	J.H.D.	Working years of production knowledge employees	J.H.D.
Education of production knowledge employees	J.H.D.	Working years of marketing employees	J.H.D.
Motivation level of production knowledge employees	J.H.D.	Motivation level of marketing employees	J.H.D.
Marketing network	Q. No.14	Number of marketing employees	J.H.D.
Profit increase	J.H.D.	Education of marketing employees	J.H.D.

The review the questionnaire, please see Supplementary 1, to see the model of the equation, please see Supplementary 2.

4.3. Analysis of the Simulation Results

According to the above description, this paper uses 2005 as the base year for simulation. The simulation step length is one year and the time frame for the simulation is from 2005–2020. The results are shown in Figures 7–9.

From the simulation results, we can find that the curve of 2005–2014 matches the development of JMC: in 2005 JMC reach a strategic agreement with Ford Corporation. In 2007, it launched the V348 vehicles which gained high popularity in the market. In 2010, it launched the S350 series. In 2014, its business indicators have reached a new record. In that year, its sales revenue was 25.5 billion yuan and its sales were 2.76 million. These facts can well account for the simulation result of the model we build. From the model we can see that from 2005 to 2006 there was a rapid development stage. From 2006 to 2009 the development has slowed down while, from 2009 to 2014, there is another rapid development period. From the simulation of the production innovation capability of JMC we can see with the launch of new vehicles in 2007 and 2008 and after 2010 there is a rapid development period; from the simulation of market innovation capabilities of JMC we can see between 2007 and 2011 there was a rapid development; between 2011 and 2012 there was a short stop and after 2012 it regained vitality and maintained rapid development.

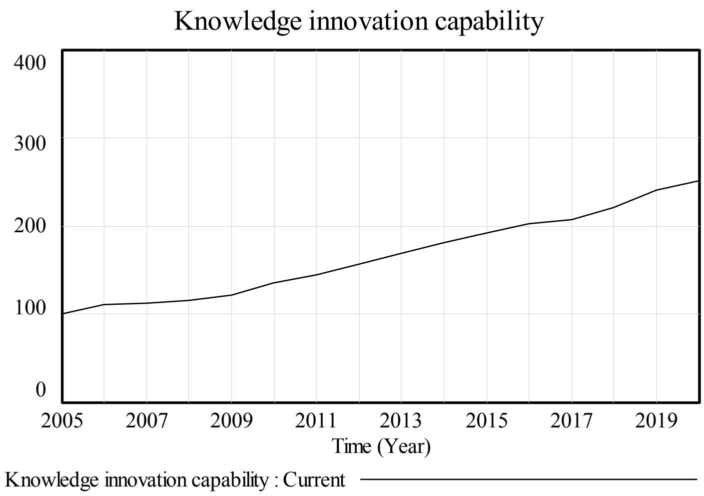

Figure 7. Simulation result of knowledge innovation capability.

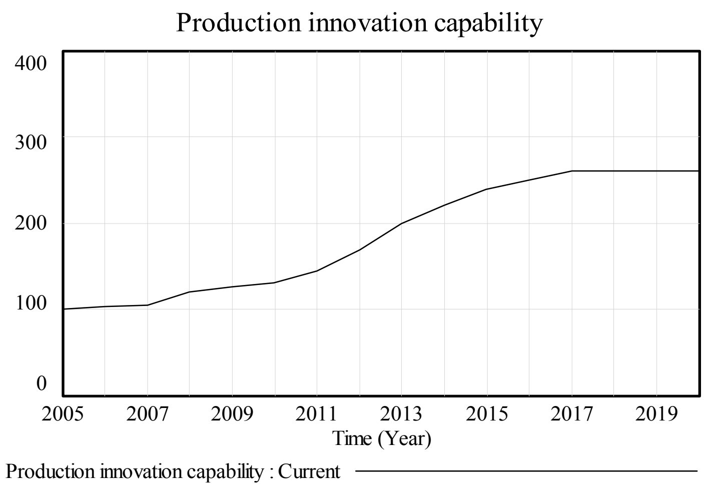

Figure 8. Simulation result of production innovation capability.

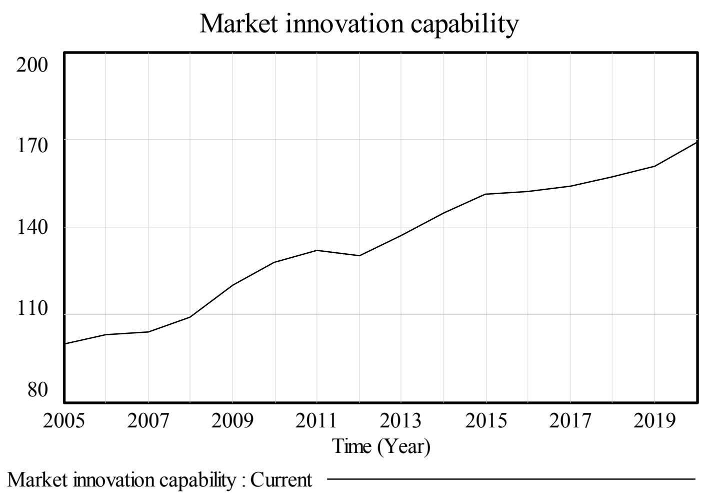

Figure 9. Simulation result of market innovation capability.

From the above analysis, we can find that the simulation results seem to follow with the reality and hence prove the sustainable innovation model proposed in section 3. From the forecast results of the model, we can see that between 2015 and 2020 the knowledge innovation capability and the market innovation capability will keep growing but the growth rate will not be accelerated while the production innovation capability will slowly grow until 2017 which we think may more or less related with the turndown of the automotive industry. From another perspective, it also shows that although production innovation capability will remain stagnant for the near future, it will not influence the company's input in R&D and will not influence its expansion in the market.

5. Discussion

This paper combines both empirical study and case study to systematically study the factors which influence sustainable innovation. The main findings are as follows:

(1) Defining what is sustainable innovation and its characteristics. Sustainable innovation indicates the process of which within a long period, depending on the continuous learning of its employees, the enterprise continuously implements innovative integration of its key resources (knowledge, production, and market) to obtain uninterrupted growth and sustainable development. It has the following characteristics: persistence, human orientation, a dynamic and systematic nature, continuous growth of economic benefits, and sustainable development of enterprises.

(2) Carrying out the empirical study on the factors influencing sustainable innovation. The factors which influence sustainable innovation are diverse and complicated. We believe the internal factors are the fundamental ones. Based on innovation theory, dynamic capability theory, and knowledge-based theory, this paper establishes a theoretical framework of the factors influencing sustainable innovation.

(3) Carrying out a case study on the factors influencing sustainable innovation. Taking JMC as an example, based on a system dynamics model, this paper has tested the effectiveness of the theoretical framework of sustainable innovation factors. The simulation results demonstrate that, from 2005–2014, the curve matches with the reality of JMC. Furthermore, it forecasts the future development of JMC in the next five years. The case study further proves that the theoretical framework this paper builds has high applicability.

Compared with previous studies, this paper has inherited the view that sustainable innovation capability has human and system characteristics [29], but the difference is that this paper makes these characteristics more specific. This paper systematically points out that the key factors which influence sustainable innovation are knowledge innovation capability, production innovation capability, and market innovation capability, and argues that knowledge workers can exercise positive effect on the three innovation capabilities. Furthermore, based on questionnaires and interviews, combined with the structural equation model, this paper has tested the effectiveness of the model. The results show that knowledge learning capability and knowledge creation capability have a positive influence on knowledge innovation capability; knowledge transferring capability and production equipment level have a positive influence on production innovation capability; profit-making capability and marketing capability have a positive influence on market innovation capability.

In the process of conducting this study, although we sought to be objective and rigorous, this study still has some limitations. Restricted by time and expenditures, the data collected are mainly from enterprises of Jiangxi, Guangdong, Zhejiang, Hubei, Hunan, and Sichuan provinces. If we can have more sample data from larger scale, the results of this paper will be more convincing and representative. Aiming at the limitation, in the next step we should expand the sampling range and cover more different enterprises. As such, the results of empirical studies will be more persuasive and representative.

6. Conclusions

This paper combines both empirical study and case study to systematically study the factors which influence sustainable innovation. The sustainable innovation of enterprises is a hot issue which attracts great much attention from both academia and the business community. There is a lot of room for research in the future. This paper only focuses on the determinants of sustainable innovation. In the investigation process, the author strongly sensed that enterprises are more interested in questions like how to realize sustainable innovation and what kind of outcomes can be produced. Therefore, this will be the direction of future research.

Based on the literature review, this paper proposes that the sustainable innovation capability of enterprises is comprised of knowledge innovation capability, production innovation capability, and market innovation capability. However, questions like what is the proportion of each capability in sustainable innovation and whether different innovation enterprises have a different constitution of the three capabilities are not addressed in this paper. This can be the next research focus.

Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/8/5/425/s1, Supplementary 1. Enterprise Sustainable Innovation Factors Questionnaire, Supplementary 2. The Equation of System Dynamics Model.

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Abbreviations

The following abbreviations are used in this manuscript:

JMC	Jiangling Motors Co., Ltd.

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