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Research Article

Analysis on the Development of Automation and Intelligence in China's Manufacturing Industry—Taking R & D Collaboration among Automobile Enterprises

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With the development of intelligence for automated automobile industries in China, the traditional R&D mode of enterprise has evolved from integrated internal innovation within a single enterprise to collaborative innovation among enterprises, which makes enterprises break the limit of the organizational boundaries to seek for the right partners and cooperation. However, the R&D environment among business partners and the mismatch between R&D and management have greatly affected the development of intelligence for automated industrial. Based on synergetic, from the perspective of collaborative R&D among automobile companies, this paper takes the collaborative R&D between Renault-Nissan Alliance and Dongfeng Motor Group as the research object, conducting quantitative analysis using regression models and structural equation models with 423 valid questionnaires collected in three months (from October 2017 to May 2018), and attempting to reveal the situational context in the distributed innovation network as well as how the dynamic collaborative behaviors among R&D enterprises act on "collaborative R&D performance." The results show that first, the four "collaborative contexts"–strategic context, cultural context, institutional context, and network context–have a significant positive correlation with the level of collaborative R&D; second, the three "collaborative behaviors"—knowledge sharing, information sharing, and specific asset investment—have a significant positive correlation with the level of knowledge growth; and third, the level of collaborative R&D and knowledge growth have a significant positive correlation with R&D performance. Thus, it is revealed that not only are there situational contexts among the R&D and innovation activities of the core enterprises but also dynamic collaborative behavior. This creates a new perspective for the research on the development of intelligence for automated automobile industries in China among automobile companies.

1. Introduction

Today, the world is experiencing a new round of scientific and technological revolution and industrial transformation with information technology as its core. Technically, for all enterprises, no technological innovation can be achieved without cooperation, and core enterprises are no exception, as these enterprises themselves are open. The ever-changing market and technological environment have made different innovation entities form a network of technological innovations, which has become an important organizational form of technological innovation for enterprises. From the perspective of enterprises, the new round of innovative activities is no longer restricted to the R&D and innovation within the internal technological innovation network of the enterprise as the external R&D networks are emphasized to obtain resources. The distributed innovation network has become an important way for core enterprises to acquire dispersed knowledge. Distributed innovation networks can effectively search for, integrate, and spread knowledge that is across geographical boundaries, thereby creating an R&D environment that facilitates sharing of technical knowledge and collaboration and enhances enterprises' innovation capabilities. Therefore, with the distributed innovation network, the design of collaborative R&D, the construction of the collaborative working platform, and collaborative manufacturing have become the trend that can effectively promote the independent innovation capability of core R&D enterprises and help them realize leap-forward development.

It is reported on the website of the Ministry of Science and Technology of China that in 2017, the total number of scientific and technological papers that are published internationally increased by 70% compared with 2012, ranking second in the world; the international citation number of scientific and technological papers ranked second in the world. The number of patent applications and authorizations ranked first in the world; the number of effective patents ranked third in the world. The national transaction volume in technological contracts reached 13 trillion yuan. The total number of high-tech enterprises in China exceeded 136,000; their R&D investment accounted for more than 50% of the national total; their patents accounted for 40% of the national total. The contribution ratio of science and technology progress rose from 52.2% in 2012 to 57.5%. The ranking of national innovation ability rose from the 20th place in 2012 to the 17th. Despite the remarkable achievements in terms of scientific and technological innovation, China's innovation system is still an isolated island with many "innovation islands." The internal coordination and integration are not perfect. Problems such as dispersed and fragmented innovation resources and poor collaboration are prominent in the new situation, which limits the knowledge spillover [1] among the "islands." They also become a barrier for R&D collaboration among the core enterprises as well as leap-forward innovation development, being an unavoidable realistic issue in the implementation of collaborative R&D activities.

In the past, research on collaborative R&D mostly adopted the collaborative innovation model, which takes enterprises as the core of collaboration and other R&D entities (including universities, research institutes, and governments) as a subsidiary. Through the effective optimization and integration of resources among R&D entities, the collaborative effect of the whole innovation system is achieved [2]. The previous study on collaborative R&D performance among R&D enterprises focuses mainly on enterprises, universities, and research institutions from the perspective of driving factors [3, 4] for innovation, operational mechanisms [5, 6], network centrality, geographic proximity [7, 8], and collaborative surplus [9]. For the correlation within collaborative innovation, the evolutionary game model is commonly used for analysis. However, for the research on the correlation between "collaborative context," "cooperative behavior" and R&D performance, there is still much room for improvement in R&D collaboration among core enterprises, and theoretical perfection and quantitative verification are urgently needed.

2. Literature Review and Research Hypotheses

2.1. Data Collection

2.1.1. Selection of Respondents and Samples

(1) Selection of Respondents. This paper mainly selects the industries closely related to R&D-automobile manufacturing enterprises as the research object. Such enterprises are technology-intensive enterprises, and the technology R&D activities among multinational automobile enterprises show the characteristics of distributed cooperation. Dongfeng Motor Corporation, France Renault Automobile companies, and the three automobile manufacturing industries of Japan's Nissan are at the core of the automobile industry. They are not only large in scale but also possess a lot of knowledge gaps. The R&D system of the automobile manufacturing industry has the characteristics of both systematic and complexity. For example, engine technology is a common technical problem in my country's automobile manufacturing industry. To break through this technical bottleneck, it may not be possible to rely on the R&D department of my country's automobile enterprises. This requires collaborative R&D with the multinational automobile manufacturing industry with advanced engine technology.

As China's auto market is facing changes in the trend of lightweight, electrification, intelligence, networking, and sharing, the world's top 500 auto companies-Dongfeng Motor Corporation (ranked 68th), French Renault (ranked 157th), and the "Golden Triangle" of Japan's Nissan Motor (ranked 44th) chose to form an alliance again and set up a new joint venture, "Egypt New Energy Vehicle Co., Ltd. (e GT)." To jointly develop and produce electric vehicles in China.

(2) Selection of Samples. First, by searching and consulting the literature on "distributed innovation," "core enterprise," "R&D synergy," "collaborative situation," "collaborative behavior" and "synergy effect," and summarize the results based on organizational behavior theory and multi-agent system theory.

Secondly, in order to ensure the scientific nature and rationality of the questionnaire design, 56 small samples were used to conduct a preliminary questionnaire survey, and the reliability (CITC) was used to purify the questions, items, delete items that obviously affect the quality of the questionnaire, and at the same time modify some items to form a formal questionnaire. The second stage is the formal investigation stage.

Third, the survey time of the large sample questionnaire was from October 2017 to May 2018, which lasted for more than 7 months. In order to ensure the validity of the sample data, this paper selected the research and development status of the automobile manufacturing industry and enterprises themselves. Technical R&D personnel, project managers, and middle and senior managers of enterprises issue questionnaires and conduct in-depth interviews with technical experts. Among them, the research objects are mainly the technology R&D departments of the passenger car companies of the three companies (including the modeling department, trial production department, vehicle department, body department, electronic and electrical department, classis department, testing department, powertrain).

2.1.2. Data Collection. The samples for this study are the R&D staff of Renault-Nissan Alliance and Dongfeng Motor Group in Wuhan, including general R&D personnel and project managers. To improve the reliability, relevance, and effectiveness of the questionnaire, it was mainly distributed in two ways: electronically and on-site. The survey and data collection lasted for 3 months (from October 2017 to May 2018). A total of 600 questionnaires were distributed, and 576 questionnaires were collected within the specified time, of which 423 were valid. The effective questionnaire collection rate is 78.97%. In terms of gender, males account for 72.8% and females for 27.2%; in terms of age, 18.9% are under 30 years old, 61.4% are aged 31–40 years old, and 19.7% over 40 years old; in terms of education, 48.5% have a bachelor's degree, 43.2% have a master's degree, and Ph.D. account for 8.2%; in terms of position, assistant engineers account for 21.1%, engineers account for 66.3%, and senior engineers 12.6%.

2.1.3. The Reliability of Questionnaire Design. The variables in this study were measured using a 5-point Likert scale ranging from "completely disagree." Fowler has pointed out that respondents' answers to questions are inaccurate, which can lead to bias in the data obtained. This study minimizes the negative impact of respondents who do not understand relevant information and those who are unwilling to participate in answering questions. Regarding the number of questions and the arrangement of the items, the items that affect the synergistic effect of R&D are placed behind the items measured by other factors, so that the collection of questionnaire data is more reasonable, scientific, and reliable.

2.2. Variable Measurement and Indicator Selection

2.2.1. "Collaborative Context" and R&D Collaboration Level. The "collaborative context" means that, instead of accumulating by simple repetition, knowledge innovation and sharing among enterprises are dynamic and related to specific situational contexts. Academic research on "collaboration context" is based on the concern of "situational factors." The current theoretical perspectives on situational factors can be divided into three categories: based on the physical environment, the first category studies from the users' perspective, dividing "situational factors" into the material environment, the social environment, and the time factor [10]; based on conditions, background, and environment that are related to knowledge or knowledge activities, the second category studies the impact of "situational factors" on knowledge transfer from the perspective of knowledge context [11, 12]. The third category is based on a macro-micro level perspective: the research at the macro-level is mainly on the economic, political, scientific, and technological policies and regulations of the whole society; the research at the meso-level is mainly on development strategy, relationship strength, and physical distance; the research at micro-level is mainly on organizational culture, structure, and management [13]. Although the studies are conducted from different perspectives, they all affirm the role of situational factors and fully illustrate that the R&D collaboration process among enterprises itself is a situational context, that is, within the activity system consisting of objects, actions, and operations, all activities that are of background relationships, participants, and products together constitute the situational context [14].

In this paper, "collaborative context" is defined as the factors related to collaborative R&D among core enterprises, namely, strategic context, cultural context, institutional context, and network context. Among them, "strategic context" and "cultural context" are the objective situational factors at the organizational level; "institutional context" and "network context" are objective situational factors beyond the organizational level. "Strategic context" refers to external organizations and forces that have an impact on the formulation and effectiveness of corporate strategies, including the macroeconomic environment, political and legal environment, social and cultural environment, technological environment, and competition faced by enterprises. "Situational factors" are various uncontrollable external forces of the enterprise, while the "strategic context" of the enterprise can be reformed by changing the activities of the enterprise. For example, the game relationship between enterprises will also promote the formation of new contexts. For enterprises, the "strategic context" and the formation of corporate strategies, program selection, implementation, evaluation, and regulation together constitute a continuous and parallel process, that is, the strategy is a dynamic process which is taking shape while being implemented. The analysis of "strategic context" needs to run through the strategic process of the enterprise from the beginning till the end. R&D activities should not deviate from the corporate strategy. Instead, under the premise of "strategic context," they should continuously carry out innovation and transformation centered on corporate strategy, thus dynamically forming and implementing the strategy.

The "cultural context" provides a supportive internal and external environment for interenterprise collaboration, affecting the behavior and psychology of the entire team and all individuals. It is an inherent condition for carrying out collaborative innovation activities. The significance of collaboration among core enterprises lies in collaborative innovation. However, in the process of collaborative R&D, when innovative entities with different organizational cultural characteristics work together, cultural conflicts will inevitably arise. The root lies in that cultural differences among core enterprises make it possible for different cultures to meet and come up with creative ideas, which facilitates the creation of innovative activities.

The "institutional context" is based on the multilateral external relationships of the enterprise, which affects the set of rules for its social behavior by shaping the operational mode and market transaction mode of the enterprise. "Institutional context" is the institutional requirement of a collaborative innovation entity. It needs to standardize the behavior of the collaborative innovation entity as well as promote its development. It is the external condition for collaborative innovation activities. The "institutional context" reflects the depth, breadth, and intensity of the collaboration among collaborative innovation entities, which facilitates the formation of a community of interest among the various collaborative entities.

With increased innovation difficulty and complexity, the innovation model has seen the leap from "linear mode" through "planar mode" to "tridimensional network mode." "Network" has become the fastest-growing quasi-market organization between enterprises and markets. It provides enterprise organizations with a borderless innovation context, promotes the transformation from collaborative innovation activities to a collaborative innovation network, and enables collaborative communication and sharing among enterprises. In the network context, the core R&D enterprises participating in the collaboration establish a reciprocal and flexible relationship through formal or informal agreements and form a network collaboration whose overall innovation ability is greater than the sum of individual innovation abilities. It not only enhances the flow and transfer of R&D knowledge and knowledge growth, but also exploits the advantages of the economy of scale to the full, optimizes resource allocation, and promotes R&D performance. Based on the above analysis, the following hypotheses are proposed:

Hypothesis 1 (H1): the "strategic context" is positively correlated with the R&D performance

Hypothesis 2 (H2): the "cultural context" is positively correlated with the R&D performance

Hypothesis 3 (H3): the "institutional context" is positively correlated with the R&D performance

Hypothesis 4 (H4): the "network context" is positively correlated with the R&D performance

2.2.2. "Collaborative Behavior" and the Knowledge Growth Level. Based on the basic concepts of synergetics, Osbome and Gaebler [15] proposed that "cooperative behavior" is an essential behavior of organizations, and organizations achieve collaboration by sharing resources, services, and operations. The research perspectives on "collaborative behavior" are divided into six categories: the first category divides "collaborative behavior" into investment collaboration, operational collaboration, sales coordination, and management coordination according to the value chain theory [16]; from the perspective of asset nature, the second category divides collaborative behavior into implicit and explicit collaboration [17], or tangible asset and intangible asset collaboration [18]; the third category divides collaborative behaviors into synchronous and asynchronous collaboration from the perspective of time series [19]; the fourth category divides organizational collaborative behaviors into personnel collaboration, task collaboration, and target collaboration from the perspective of the factors and content of behavior formation [20]; the fourth category divides the organization collaborative behaviors into autonomous collaboration, loose collaboration and collaboration from the perspective of organizational structure [21]; the sixth category proposes interorganizational collaborative behavioral strategies from the perspective of strategy, capability system, process collaboration, dynamic alliance and network connection [22, 23]. Through the review of existing research, the author finds that most of the research on "collaborative behavior" focus on individual behavior, and few focus on the organizational (or team) level–the collaboration among R&D enterprises. In addition, currently, the research on collaborative effects mainly focuses on enterprise mergers or the internal collaborative effects of the enterprise rather than the collaborative behaviors among independent enterprises. In view of this, the author believes that "collaborative behavior" is within the collaborative context, through integrating and sharing internal and external resources, to implement internal collaboration and external collaboration, thus realizing mutual collaboration and development. The collaborative behaviors of enterprises are divided into three levels: knowledge sharing, information sharing, and specific asset investment.

Knowledge, especially scarce knowledge, is a valuable resource, which not only brings considerable benefits to the owners, but also serves as a key factor in the formation of cross-organizational collaborative innovation. Knowledge is the most important strategic resource of the organization, and knowledge sharing is an important consideration for enterprises to choose collaborative innovation. Lin [24] believes that effective "knowledge sharing" refers to the process of knowledge exchange among innovation network entities or different organizations. The purpose is to increase the utility value of knowledge and therefore increase the performance of the enterprise through sharing. Due to the differences in the formation and accumulation of knowledge among enterprises during the R&D process, for one thing, the heterogeneity of the enterprise is determined; besides, the diversity of knowledge structures among enterprises is also determined. It is shown as the potential differences of knowledge, that is, the nonuniformity of knowledge distribution in the organization. The existence of knowledge potential difference makes knowledge spread from high-potential individuals to low-potential individuals. Besides, it is shown as the diversity of knowledge, which not only refers to the multigroup of knowledge sharing among enterprises, but also means that it becomes a complicated and ever-changing behavior to share knowledge among enterprises, where there are many difficulties and obstacles. Take interenterprise technology R&D activities as an example. In collaborative enterprises based on a certain technology or knowledge, different enterprises, as well as contributors and recipients of knowledge within each unit of the enterprise, are more inclined to have completely different organizational frameworks, research methods, and coding schemes [25]. Through the knowledge flow, technology cross-over, and personnel exchange among enterprises, the knowledge and innovative technology in R&D will be effectively planted into the member enterprises, thus strengthening and renewing the core technology of the enterprise and realize the knowledge growth in the enterprise as well as in the whole innovative network. While the most effective way to achieve knowledge sharing and technological collaboration is to promote cooperation among enterprises. The process of collaboration facilitates knowledge transfer and absorption and integrates knowledge exchange between enterprises.

Information is a shared property. It does not cause one party to lose anything while the other party uses it. "Information sharing" is the process where information forms an image of a source through a certain mapping relationship. R&D cooperation is a kind of information-based cooperation between enterprises. Enterprises usually rely on establishing R&D alliances to cooperate, realize technological innovation, and benefit from it. From the perspective of utility gain (increased utility of information generated by sharing information resources), for information sharing based on information technology, the utility of information resources for each enterprise is reflected in that they can be used not only by the enterprise itself but also be shared with other enterprises through a sharing system. Assume that the information resources are initially available to only one enterprise and are not shared with other enterprises. At this time, the gain of information sharing is $SU_1 = 1$ when another enterprise shares the information, for those two enterprises, the information resource is used by themselves and shared with another enterprise. Now, the gain in information sharing is $SU_2 = 2$. When the number of enterprises increases to n, the gain of sharing information is: $SU_n = n(n-1)$ that is

$$SU_n = \begin{cases} 1, & n = 1, \\ n(n-1), & n > 1, \end{cases} \quad n = 1, 2, 3, \ldots, N. \tag{1}$$

It can be seen that when the number of enterprises that share the information resource exceeds 10, the gain value of sharing information resources will increase rapidly. When the number of enterprises n, is large, the gain of sharing information resources is approximate n^2.

$$SU_n = \lim_{n \longrightarrow \infty} n(n-1) = n^2. \tag{2}$$

For the classification of asset specificity, Yan and Yuan [26] included intangible technological assets in the research based on the Williamson classification. Among them, intangible technological assets refer to intangible assets that will bring the users financial benefits, such as patent technologies, non-patent technologies, technological secrets, computer software that relies on knowledge, intelligence, techniques, and skills, as well as the integration of talent quality and various licensing that are closely related to technology [27]. Intangible technological assets are divided into three categories: patents, proprietary technologies, and industrial copyrights. In the collaborative R&D activities, the investment in specific assets is more reflected in the investment of intangible technological assets. In the context of distributed innovation, the reason R&D companies choose collaborative R&D is not only to strengthen their own ability and consolidate their market position. What is more important is the irreplaceability of such assets, which makes intangible technological assets exclusive to some extent. Clearly, the more unreplaceable and necessary are the intangible technological assets, the more exclusive are the assets. As long as a certain technology is necessary for the cooperation between the two parties, the success of cooperation between enterprises will be enhanced, and the enterprises will obtain advanced technology or core technology from each other, which will facilitate the rapid improvement of knowledge and help to consolidate and enhance the competitiveness of the enterprise. Based on the above analysis, the following hypotheses are made:

Hypothesis 5 (H5): knowledge sharing is positively correlated with the knowledge growth level.

Hypothesis 6 (H6): information sharing is positively correlated with the knowledge growth level.

Hypothesis 7 (H7): specific asset investment is positively correlated with the knowledge growth level.

2.2.3. Studies on R&D Collaboration Level, Knowledge Growth Level, and "R&D Performance". Previous studies on "R&D performance" can be divided into two categories: first, scholars holding knowledge base views believe that the distributed innovation network is beneficial for the spread and collection of knowledge [28]; while scholars holding organizational economics views think that due to the geographical distance between the R&D departments, cross-boundary knowledge spread, and sharing requires high coordination and communication costs, so the economies of scale or scope may no longer exist [29]. Problems such as the conflict of the incentive mechanisms will hinder knowledge spread, reduce the efficiency of knowledge sharing, and eventually lower the R&D performance. Therefore, the relationship between the distributed R&D activities and R&D performance is not definite. In that case, the interaction and collaboration among the members within the network are required to understand the specific situational context and dynamic characteristics of the distributed innovation network and the dynamic relationships among the members of the network. The interaction can be realized in the collaborative context through cooperation and coordination among enterprises; collaboration is the result of interaction: the implementation of R&D activities improves the interaction among cooperating enterprises, and the long-term interaction can institutionalize the inter-enterprise relationships, so the interaction results in collaboration.

Collaborative behaviors and sharing criteria between enterprises not only promote cooperation and knowledge sharing among partners, but also increase the speed and efficiency of knowledge distribution. Frequent and in-depth R&D interactions accelerate the exchange of knowledge among R&D enterprises, which in turn enhances the ability of information transfer and improves knowledge absorption. It helps R&D personnel to deeply understand and develop R&D knowledge and helps to improve the level of R&D collaboration as well as the knowledge growth level.

According to Zhou et al. [30], in the interactive process of knowledge innovation and distribution, the whole cluster innovation network and the knowledge level of the enterprise are constantly changing. The reasonable measure of the changing performance includes the efficiency of the increase of knowledge growth, and then with the dynamic growth of knowledge level, the knowledge stock in the entire network is largely promoted. Based on the above analysis, the following hypotheses are made:

Hypothesis 8 (H8): the R&D collaboration level is positively correlated with the knowledge growth level

Hypothesis 9 (H9): the R&D collaboration level is positively correlated with the network performance level

Hypothesis 10 (H10): the knowledge growth level is positively correlated with the network performance level

In summary, the refined theoretical model and research assumptions constructed in this paper are shown in Figure 1.

3. Reliability and Validity Test of Variables

3.1. Reliability Test. Reliability analysis is used to test the degree to which the variance of the observable variable explains the latent variable. The greater the reliability, the higher the degree of covariance of the observed variables used to explain a latent variable. In this study, the Cronbach's coefficient method was used as a reliability index to measure the internal consistency of the items when Cronbach's coefficient was greater than 0.7, it indicated that the internal consistency of the measurement items was high, and the items were reserved. In addition, the CICT (Corrected item-total) validity evaluation of the correlation coefficient for the sum of items measuring the same variable and other items is also used to improve the convergent validity of the measurement. If CICT is less than 0.3, the item will be deleted; If the CICT value is between 0.3 and 0.5, if deleting the item can improve the overall coefficient of the scale, it will be deleted.

(1) For the measurement of "strategic context", the author refers to the Motor scale of Narver and Slater [31] and the questionnaires of Zheng [32] and Wang [33], and sets 6 questions for "strategic context" from three aspects: R&D strategy consensus, inter-enterprise R&D strategy matching degree, and collaborative vision; for the measurement of "cultural context", the author refers to Li [34], A questionnaire designed according to Denison's [35] organizational culture model, the questionnaires of Hu et al. [36], Zheng Xiaodan and Wang Xiaojing, and sets four questions for "cultural context" from three aspects: knowledge sharing atmosphere, the cultural matching degree and the collaborative concept; the measurement of "institutional context" is based on IBV (Institutional-based View of Business Strategy) proposed by Peng [37], who believes that the institutional situation is an independent or endogenous variable that affects the strategic behavior of the company, and four questions are set from two aspects: the reward system and the confidentiality system; for the measurement of the "network context," the author refers to the research of Freeman [38] and Martin and Sunley [39] and Inkpen and Tsang [40], and sets seven questions from the perspective of R&D network platform construction.

(2) For the measurement of the "knowledge sharing level," the author refers to the research of Hansen [41], Bartol and Srivastava [42], Dooley and O'Sullivan [43], and sets six questions from four aspects: willingness to share, R&D data, research and leadership; for the measurement of the "information sharing level," the author refers to the research on the impact of information sharing on R&D collaboration between enterprises by Li and Yang [44], and sets 11 questions from joint technology development, technology and experience exchange, and information exchange among R&D personnel; the measurement of the "specific asset investment" is based on field interviews and the R&D characteristics and attributes of the research objects, and six questions are set from the provision of specialized R&D sites, R&D equipment, and patented technologies, etc.;

(3) The measurement of the "knowledge growth level" is based on the research of Yu [45], and eight questions are set for the increase of patent applications and the increase of knowledge stock, etc.

(4) The measurement of "R&D performance" is mainly based on the research of Griffin and Page [46] and Wang Xiaojing. Combined with interviews and corporate practice, eight questions are set on the success rate of R&D projects, the improvement of innovation capability, and the shortened R&D cycle.

The data collected in this paper is divided into two stages: in the first stage, to ensure that the research results are scientific, 56 small samples were randomly selected for the pre-survey (which lasted for one and a half months, from October 12 to November 28, 2017). To ensure the validity of the sample data, the presurvey was conducted on randomly selected R&D technicians, project managers, and personnel who have a good understanding of the R&D status of the Renault-Nissan Alliance and Dongfeng Motor Group. The questionnaires were distributed on-site, and the reliability and validity of the scale were analyzed. Correct Item Total Correction

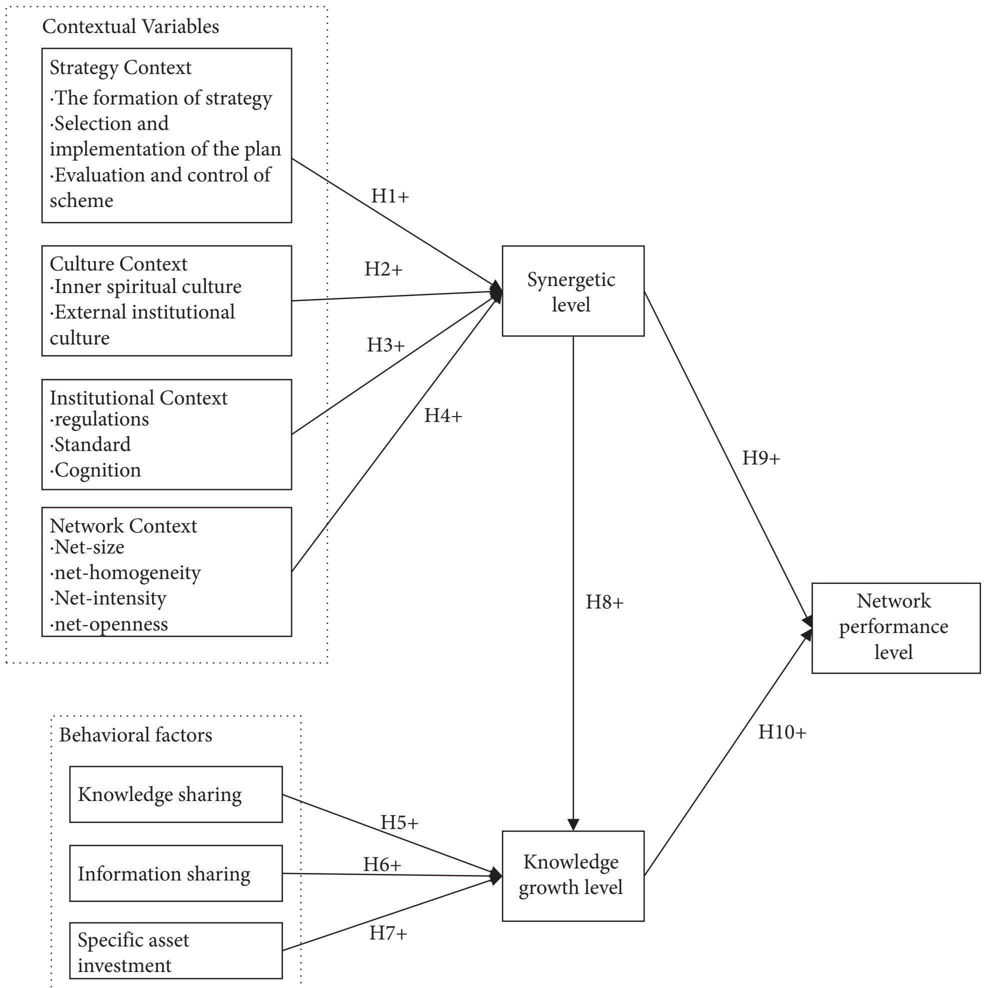

Figure 1: Theoretical models and research hypotheses of quantitative empirical research.

(CITC) is applied to purify the questions and delete those questions that significantly affect the quality of the questionnaire, thus forming the final questionnaire. The second stage is the survey time of the large sample questionnaire, which was from October 2017 to May 2018, which lasted for more than 7 months. In order to ensure the validity of the research and development status of the automobile manufacturing industry and the enterprises themselves. Technical R&D personnel, project managers, and middle and senior managers of enterprises issue questionnaires and conduct in-depth interviews with technical experts. Among them, the research objects are mainly the technology R&D departments of the passenger car companies of three companies (including the modeling department, trial production department, vehicle department, body department, electronic and electrical department, chassis department, testing department, powertrain, etc.).

3.2. Validity Test. Firstly, in this study, Cronbach's α coefficient method is used as a reliability index to measure the internal consistency of the questions. When Cronbach's α coefficient of the variable is greater than 0.7, the internal consistency of the questions is relatively high, and the reliability requirement is met. Secondly, the exploratory factor analysis method is used to examine the dimensions of the internal structure of the purified scale. According to the KMO and Bartlett spherical tests, it is judged whether the sample is suitable for factor analysis. If the KMO is above 0.9, when the significance of the Bartlett spherical test is less than or equal to the level of significance, it is suitable for factor analysis. Finally, the factor rotation is performed by the maximum variance method. When the factor load of the measurement items is all greater than 0.5, the questions have relatively good internal structural validity..

(1) Reliability and validity test on factors affecting the collaborative context between the Renault-Nissan Alliance and Dongfeng Motor Group

After purifying the 21 initial measurement items of the collaborative context between the Renault-Nissan Alliance and Dongfeng Motor Group, 21 were retained. Exploratory factor analysis was conducted using SPSS 17.0 on factors affecting the "collaborative context" between enterprises (see Table 1 for detailed results).

Table 1: Reliability and validity tests on factors affecting the collaborative context between the renault-nissan alliance and dongfeng motor group.

Dimension	α coefficient	Item	Factor
Strategy context	0.834	Q1-1	0.805
		Q1-2	0.797
		Q1-3	0.810
		Q1-4	0.799
		Q1-5	0.819
		Q1-6	0.814
Culture context	0.762	Q1-7	0.586
		Q1-8	0.686
		Q1-9	0.687
		Q1-10	0.799
Network context	0.895	Q1-11	0.880
		Q1-12	0.866
		Q1-13	0.887
		Q1-14	0.893
		Q1-15	0.881
		Q1-16	0.885
		Q1-17	0.871
Institutional context	0.825	Q1-18	0.813
		Q1-19	0.764
		Q1-20	0.782
		Q1-21	0.752
KMO	0.902		
Bartlett spherical test	$P = 0.000$		

(2) Reliability and validity test on the factors affecting the level of "collaborative behavior" between the Renault-Nissan Alliance and Dongfeng Motor Group (see Table 2 for the results and analysis).

(3) The impact of the collaboration on the level of knowledge growth between the Renault-Nissan Alliance and Dongfeng Motor Group (see Table 3 for the results and analysis).

(4) The impact of knowledge growth levels on network performance levels between the Renault-Nissan Alliance and Dongfeng Motor Group (see Table 4 for the results and analysis).

As shown in Tables 1–4, the KMO values are all above 0.8, and as shown in the Bartlett spherical test, the significance levels are all 0.000, indicating that the sample data are of high structural validity. And the maximum load value of each factor is greater than 0.5, indicating that the scale has good convergent validity and differential validity. The results of the reliability test show that the overall α reliability coefficients of each structural dimension are greater than 0.7, indicating that the internal consistency and reliability of the scale are relatively high. .

3.3. Research Model Test. After completing the reliability and validity test of the questionnaire, the fitting effects of the research model were measured by x^2/df, RMSEA, GFI, AGFI, PGFI, and other indicators (see Table 5 for the correlation coefficient).

Table 2: Reliability and validity test on the factors affecting the level of "collaborative behavior" between the renault-nissan alliance and dongfeng motor group.

Dimension	α coefficient	Item	Factor
Knowledge sharing	0.836	Q2-1	0.865
		Q2-2	0.789
		Q2-3	0.799
		Q2-4	0.788
		Q2-5	0.794
		Q2-6	0.796
Information sharing	0.896	Q2-7	0.885
		Q2-8	0.883
		Q2-9	0.887
		Q2-10	0.888
		Q2-11	0.882
		Q2-12	0.878
Specific asset investment	0.838	Q2-18	0.801
		Q2-19	0.812
		Q2-20	0.797
		Q2-21	0.803
		Q2-22	0.769
		Q2-23	0.844
		Q2-13	0.882
		Q2-14	0.880
		Q2-15	0.892
		Q2-16	0.891
		Q2-17	0.888
KMO	0.943		
Bartlett spherical test	$P = 0.000$		

Table 3: The impact of the collaboration on the level of knowledge growth between the Renault-Nissan alliance and dongfeng motor group.

Variable	α coefficient	Item	Factor	Item	Factor
Knowledge growth level	0.831	Q3-1	0.798	Q3-5	0.809
		Q3-2	0.801	Q3-6	0.807
		Q3-3	0.808	Q3-7	0.842
		Q3-4	0.796	Q3-8	0.844
KMO	0.838				
Bartlett spherical test	$P = 0.000$				

For the whole model, GFI, AGFI, and NFI are 0.845, 0.833, and 0.860, respectively, which are close to 0.90. Overall, most of the fitting indicators have reached the standard, indicating that the structural equation model established in this study has a good fitting effect.

3.4. Research Hypothesis Test. Based on the variable measurement method, the measured values of each variable are obtained. The normalized path coefficients between the latent variables and their corresponding p values are shown in Table 6. The p value is used to test the significance of the relationship between variables. It is generally considered that if $p < 0.05$, then the correlation is

Table 4: The impact of knowledge growth levels on network performance levels between the Renault-Nissan alliance and dongfeng motor group.

Variable	α coefficient	Item	Factor	Item	Factor
Network R&D performance	0.908	Q3-1	0.893	Q3-5	0.895
		Q3-2	0.892	Q3-6	0.901
		Q3-3	0.893	Q3-7	0.893
		Q3-4	0.903	Q3-8	0.889
KMO			0.929		
Bartlett spherical test			$P = 0.000$		

Table 5: Model fitting index.

	Fitting index	Fitting value	The goodness of model fitting
Absolute fitting index	X^2/df	1.392	<2
	GFI	0.845	Close to 0.90
	AGFI	0.833	Close to 0.90
	RMSEA	0.031	<0.05
Absolute fitting index	CFI	0.956	>0.90
	NFI	0.860	Close to 0.90
	TLI	0.954	>0.90
	IFI	0.956	>0.90

Table 6: Research hypothesis result.

Path direction	Path coefficients	P-values	Results
Strategy context ⟶ core enterprise collaboration	0.912	***	Verification
Culture context ⟶ core enterprise collaboration	0.951	***	Verification
Institutional context ⟶ core enterprise collaboration	0.885	***	Verification
Network context ⟶ core enterprise collaboration	0.866	***	Verification
Knowledge sharing ⟶ knowledge growth level	0.834	***	Verification
Information sharing ⟶ knowledge growth level	0.921	***	Verification
Specific asset investment ⟶ knowledge growth level	0.989	***	Verification
Specific asset investment ⟶ core enterprise collaboration	0.912	***	Verification
Core enterprise collaboration ⟶ knowledge growth level	0.912	***	Verification
Knowledge growth level ⟶ network R&D performance	0.620	***	Verification
Core enterprise collaboration ⟶ network R&D performance	0.570	***	Verification

***mean $p < 0.01$

significant; if $p < 0.01$, then the correlation is very significant. The structural equation model measurement results are shown in Figure 2. The above results show that there is a significant correlation between collaborative context, collaborative behavior, and collaborative R&D performance.

4. Discussion

4.1. Collaborative Context and Collaborative R&D Capability. The hypotheses H1, H2, H3, and H4 test the relationship between the four dimensions of "collaborative context" and collaborative R&D capability. The empirical results show that "context" has a significant positive influence on the improvement of interenterprise collaborative R&D capability. With the continuous development of "context theorization," the interaction of enterprise contexts is manifested not only in the form of that between previous and current contexts [47], but rather that between the enterprise environment, organization, and people and their dynamic evolution [48].

By carrying out an on-site investigation and analyzing first-hand cases from enterprises, this paper analyzes the dynamic interaction between interenterprise collaborative performance and the contexts they are in. As was proposed by Su and Chang [49], contextual characteristics are accurately interpreted, and the "context" of all dimensions is conducive to enterprise positioning and the strategic change of core advantage.

4.1.1. "Strategic Context" and Collaborative R&D Capabilities. The improvement of R&D performance derives directly from the implementation of collaborative R&D strategies. "Strategic context" determines the fact

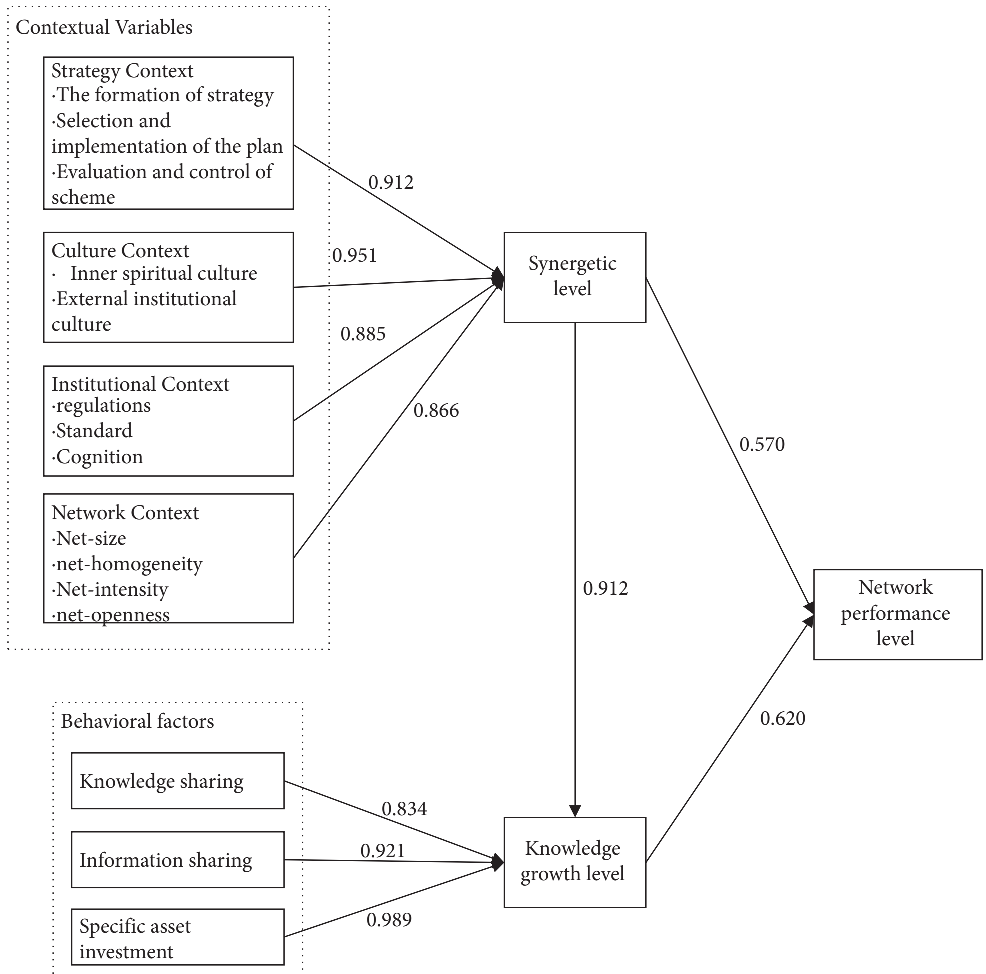

Figure 2: Structural equation model measurement results.

that the strategy is not only driven by industry characteristics and enterprise resources but also indicates directions for enterprises to conduct collaborative R&D activities. In a "strategic context," enterprises improve their competitiveness by creatively integrating resources, which indicates directions for collaborative R&D activities and directly influences the innovation achievements among enterprises [50]. Empirical analysis shows that "strategic context" can significantly positively influence interenterprise collaborative R&D performance. This means that the R&D performance depends on the enterprises' strategic choices, formulation, and implementation.

4.1.2. "Cultural Context" and Collaborative R&D Capabilities. An enterprise culture is a set of shared values and beliefs among the employees. These values and beliefs combine to formulate the common behavior guidelines observed by all employees and guide the enterprise's R&D activities. Empirical analysis shows that "cultural context" can significantly positively influence interenterprise collaborative R&D performance. This means that collaborative enterprises that share each other's cultures to a greater extent and cooperate more closely are more likely to have higher efficiency. Conversely, closer collaboration and a livelier innovation atmosphere can help formulate and further develop the collaborative culture, which is beneficial for improving R&D collaboration performance.

4.1.3. "Institutional Context" and Collaborative R&D Capabilities. The institution not only improves the institutional environment of innovation but also promotes the enterprise's R&D activities and their performance. Not only that, the institution offers an institutional guarantee for enterprises' collaborative development. Therefore, the institutional context is especially important for enterprises' collaborative R&D performance. This paper adopts Scott's institutional framework, including its three dimensions of regulation, norm, and cognition. Empirical analysis shows that institutional context has a significant positive influence on R&D performance. This implies that enterprises' collaborative R&D capability depends to a large extent on the institution the enterprises are in. A better institutional environment tends to promote the collaborative R&D activities among enterprises and their performance. Therefore, a good institutional environment is essential to improving enterprises' collaborative R&D capabilities and performance.

4.1.4. "Network Context" and Collaborative R&D Capability. Innovation's becoming increasingly difficult and complex has impelled collaborative innovation to transform into a collaborative innovation network and to form a distributed collaborative communication and sharing pattern. The inter-enterprise collaborative R&D network is premised on collaborative communication and based on knowledge sharing. The R&D participants transform, communicate, and share knowledge to realize the broadening of both a single enterprise's knowledge and the collective knowledge of the whole collaborative R&D network [51]. Empirical analysis shows that "network context" can significantly positively influence R&D performance. On the one hand, "network context" can promote the effective sharing of information and knowledge among enterprises and create a sharing atmosphere; on the other hand, it can help formulate an efficient R&D network integrating knowledge and resources.

4.2. Collaborative Behavior and Knowledge Improvement Level. The hypotheses H5, H6, and H7 test the correlation between "collaborative behavior" and knowledge improvement level. The results show that "collaborative behavior" of enterprises greatly improves their knowledge. In the R&D network, the knowledge improvement level derives from the knowledge innovation and spreading of collaborative enterprises. The network nodes are member enterprises or enterprise alliances, who, benefiting from the collaborative effect, develop a mechanism similar to the coevolution mechanism found in biogenesis or ecosystems , and have collaborative cooperation through behaviors like knowledge sharing, information sharing, and special investment. This not only improves a single enterprise's knowledge but also realizes the true win-win among collaborative enterprises.

4.2.1. Knowledge Sharing and Knowledge Improvement Level. Analysis shows that the network can significantly positively influence knowledge spread and improvement. Shared guidelines and common behavior mode can promote cooperation and knowledge sharing among enterprises [52, 53]. The gradual formulation of specific knowledge-sharing paths among collaborative enterprises can accelerate knowledge flow, thereby promoting knowledge spread in the whole network and thus improving the knowledge of enterprises. Empirical analysis reveals that "knowledge sharing" has a significant positive influence on knowledge improvement level. This indicates that the objective of enterprise collaboration is to complement each other's advantages and facilitate innovation for mutual benefit through knowledge sharing, and eventually to improve their overall knowledge and innovation capabilities.

4.2.2. Information Sharing and Knowledge Improvement Level. R&D cooperation is an information-based enterprise cooperation mode. "Information" is a stream [54], a correlation manifested by contextual data [55], and organized, structured, and generalized data [56]. R&D knowledge is organized and analyzed information. Frequent and in-depth interaction accelerates knowledge flow and thus enhances the information spreading capability and enterprises' ability to absorb it. Information sharing is an enabling and supportive factor essential to the success of cooperation. The improvement of an enterprise's learning capability is a direct outcome benefiting from R&D collaboration. Empirical analysis shows that information sharing can significantly positively influence knowledge improvement levels. This implies that interenterprise information sharing can promote their cooperation, enable them to quickly grasp each other's latest progress, and ensure efficacy. On the other hand, information sharing can encourage enterprises to learn from each other and improve their respective knowledge.

4.2.3. Special Investment and Knowledge Improvement Level. Special investment helps establish interdependence, spread and obtain information in mutual learning, and efficiently integrate resources [57]. Empirical analysis shows that special investment has a significant positive influence on the knowledge improvement level. Enterprises develop a strong symbiosis based on special investment. This enables enterprises with special investment to obtain advanced technologies or core technologies from their collaborative enterprises, which is beneficial for the collaborative R&D enterprises to reach a high knowledge improvement level. In this sense, special investment plays a positive role for both collaborative parties. Neither of them can easily quit the collaboration, which helps improve their collaborative efficiency.

4.3. Knowledge Improvement Level and R&D Performance. Hypothesis H8 tests the correlation between knowledge improvement level and R&D performance. The results show that knowledge improvement level has a significant positive influence on core enterprises' R&D performance. Scholars usually measure performance in three aspects, namely , the knowledge improvement of a single network node, the overall knowledge improvement of the whole network, and the knowledge difference between network nodes. Among them, the first two measure R&D performance from the perspective of efficiency. It is usually believed that knowledge-sharing and information-sharing behavior are the two key elements in influencing performance. Zeng et al. [58], and Yu et al. [59] believe that quick transfer and sharing of knowledge and collaborative innovation can be realized in a small network, which enables all network nodes to quickly improve their knowledge, improve the overall knowledge, and influences R&D performance. Empirical analysis shows that knowledge improvement level can significantly positively influence the R&D performance. This is because the knowledge improvement level directly influences the enterprise's own knowledge and even the overall knowledge of all the enterprises in collaboration, and eventually improves different enterprises' knowledge.

4.4. R&D Collaborative Level and R&D Performance. Hypothesis H9 tests the correlation between R&D collaborative level and R&D performance. Analysis shows that R&D collaboration level has a significant positive influence on R&D performance. That is, a higher collaborative level derives a better R&D performance shared by all collaborative enterprises. Empirical analysis shows that R&D collaborations levels can significantly positively influence R&D performance. This implies that the integration of resources, knowledge, information, and technology of collaborative enterprises is the fundamental driving force of innovation and the source of sustained competitiveness. Enterprises can innovate technology, design products that better suit the market, and establish and improve the interenterprise collaborative R&D system by means of combining independent R&D and collaborative R&D, to complement each other's advantages and improve their own and the whole performance.

5. Conclusions and Prospects

5.1. Conclusions. This study analyzes the influence of "collaborative context" and "collaborative behavior" on R&D performance under the background of distributed innovation by using the collaborative R&D of *e* GT Automobiles Co., Ltd. as a case, focusing on the collaborative R&D between Renault Nissan Group and Dongfeng Motor Corporation, surveying existing literature and carrying out onsite interviews. On the one hand, the collaborative R&D level among core enterprises is analyzed from the four dimensions of strategic context, cultural context, institutional context, and network context; on the other hand, the influence of knowledge sharing, information sharing, and special investment on the knowledge improvement level among core enterprises is also analyzed, and factor analysis and the structural equation model are adopted to test the relationship between collaborative context, collaborative behavior, and overall R&D performance. The following conclusions are drawn:

(1) In the R&D of automobiles in core enterprises, strategic context, cultural context, institutional context, and network context have significant positive influences on the R&D collaborative level. A collaborative environment is required for collaborative R&D in core enterprises. It greatly influences the collaborative R&D level among collaborative enterprises and thus determines their overall R&D performance.

(2) The realization of R&D synergy in distributed innovation networks is affected by multiple contexts (including strategic context, cultural context, institutional context, and network context) and the "dual mechanism" of collaborative behavior. The new knowledge of heterogeneity and complementarity (related and diversified) in the distributed innovation network is no longer mainly distributed within the enterprise or distributed linearly or in parallel like the traditional innovation model, but presents a network of, lines and surfaces at all levels. The "dots" in the network are the core enterprises in the network. The "lines" are the connections between multicore enterprises through R&D collaborative behaviors, and the distribution of multiple directions and intersecting lines in the network constitutes the "surface" distribution of knowledge. The development of R&D synergy in the network is often reflected by the "face", and the "face" is determined by the systematic action of "points" and "lines" under the action of collaborative situations and collaborative behaviors.

(3) The collaborative behaviors of core enterprises have significant positive influences on knowledge improvement. This implies that collaborative R&D of core enterprises helps improve the knowledge improvement of both individual enterprises and the overall network. Knowledge improvement also promotes the implementation of collaborative R&D in core enterprises and helps promote knowledge sharing, information sharing, and special investment. It helps core enterprises obtain and utilize knowledge and information during R&D, systemize their knowledge framework, spark innovation inspiration, and enhance the overall R&D efficiency.

(4) The collaborative R&D level and knowledge improvement of core enterprises have a significant positive influence on the overall performance of distributed innovation networks. This helps enhance core enterprises' knowledge sharing and technology collaboration, expand the R&D scale, bring down the R&D cost, and improve the product's innovation and R&D efficiency, which helps achieve a performance far superior to that of a single collaborative enterprise [35].

5.2. Prospects. There exists some unavoidable flaws in this study as exploratory work is included. First, limited by the secrecy involved in automobile R&D and research time, the questionnaire did not cover a wide enough range, with not so many samples either. Second, an improvement in control variable selection can be made in the future.

Considering the above limitations, we need to first collect more samples and design a more targeted questionnaire, making the study more practical and operational. Then, we used the existing literature for reference in terms of the current control variable selection and selected four contexts and three behaviors at the medium level. This paper does not touch on micro-level variables like senior managers and researchers of all levels. Therefore, the constructed model relating to collaborative context, collaborative behavior, and R&D performance is not comprehensive yet. Finally, a dynamic method is preferred for future in-depth research.

Data Availability

The data used in the article are available from the author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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