Research Article

The Innovation Ecological Model of Chinese Automotive Industry Based on Artificial Intelligence and Big Data Technology

Xiaojing Lv,1 Gui Zhang,2 Jiqing Liu,1 and Jiayu Li3

1School of Economics and Management, Hebei University of Technology, Tianjin 300401, China
2College of Economic and Social Development, Nankai University, Tianjin 300071, China
3School of Public & Management, Tsinghua University, Beijing 100084, China

Correspondence should be addressed to Gui Zhang; 2006005@hebut.edu.cn

Received 25 April 2022; Revised 9 June 2022; Accepted 14 June 2022; Published 11 July 2022

Abstract

The digitalization of the automobile industry must depend on the information technology industry. The coupling development of the two creates conditions for the realization of industry 4.0 and intelligent manufacturing. The purpose of this paper is to make an empirical study on the possibility of coupling and the coupling degree, correlation degree, and innovation ability of China’s automobile industry and information technology industry. This paper takes the intelligent manufacturing of the automobile industry as the research object. According to the current situation of China’s automobile industry, this paper uses data to analyze and predict the development level of China’s automobile industry and the gap with the foreign automobile industry. Firstly, it summarizes and analyzes the development of China’s automobile industry and information technology industry. Then, the gray correlation analysis method is used to explore the factors affecting the innovation of China’s automobile industry. It is found that the relationship between capital investment and innovation is the most significant in “industrial innovation investment.” Finally, the coupling development model of the automobile industry and information technology industry is established, and the coupling degree of the two is analyzed by using the analytic hierarchy process and the Delphi method. The research of this paper mainly focuses on the automobile industry. Under the wave of internet, other industries such as the commerce and service industry also have a strong coupling relationship with the information technology industry, which will provide a new research direction for the follow-up research of experts and scholars.

1. Introduction

The maturity of the information technology industry is gradually making disruptive innovations to industries such as transportation and logistics, especially the continued emergence and maturity of revolutionary technologies such as the Internet of Things and autonomous driving, prompting many companies, including Apple and Google, to begin a deep expansion of future automotive technology, while hardware companies such as Samsung are developing components such as autonomous driving and network connectivity with their own advantages [1, 2]. In China, Baidu has already started driverless research, LeTV has also started to develop new Internet cars in collaboration with auto companies [3], and the “Harmony Futeng” company, a joint venture between China Harmony New Energy Automobile Holdings Limited, Hon Hai Group, and Tencent Group, will leverage the strengths of the three parties in their respective fields to create the project of “Internet + Intelligent Electric Vehicle” has won the world’s attention [4]. Technology companies have shown unprecedented interest in the automotive industry, especially in the area of automotive intelligence, and the entry of information technology companies has made the traditional automotive industry feel that disruptive innovation is coming [5]. The coupling of automotive and information technology companies has become a trend, and the entry of large technology companies such as Neusoft and Huawei has made the Internet of Vehicles and the Internet of Things really get off the ground and gradually become a new growth point to drive China’s economic growth.
The transformation of the automotive industry will inevitably require a compatible production system; therefore, while focusing on product transformation, enterprises should also pay attention to the transformation of the production system at the same time. In the era of Industry 4.0 [6], the Internet of Things, represented by big data and cloud computing, will become the basis of the mesh-type production system, and activities such as R&D, production, sales, and maintenance can fully realize information interaction and communication and control through the Internet [7].

From the automotive industry, with the continued rapid development of China’s economy, China’s automotive industry has shown vigorous development in terms of quantity and structure. From an international perspective, the production and sales volume are the highest among all countries; from a perspective, in terms of automobile consumption, according to the statistics of the Traffic Management Bureau of the Ministry of Public Security, it can be seen that by 2015, the national ownership of motor vehicles and automobiles reached 279 million and 172 million, respectively, and in terms of household users, there are 31 private cars per 100 households, which shows that automobiles have become a very important part of family life. From a comprehensive point of view, although China has become the world’s largest automobile production and sales country, and China’s auto industry is large but not strong, problem is still prominent. On the one hand, some core technologies such as engines, automatic transmissions, ABS, ESP and other active driving safety systems, fuel injection systems, etc. still have not been solved, resulting in little improvement in the market competitiveness of independent brands [8]; on the other hand, the Chinese auto industry still has huge room for improvement compared with foreign auto industries in terms of intelligent manufacturing technology and coupled application of information technology.

This paper tries to find the development path of the coupling between the information technology and the automobile industry in China. This paper discusses the factors affecting the innovation of China’s automobile industry. The study found that in the “industrial innovation investment,” the relationship between capital investment and innovation is the most significant. The research of this paper mainly focuses on the automobile industry. Under the Internet wave, other industries such as the commerce and service industry also have a strong coupling relationship with the information technology industry, which will provide a new research direction for the follow-up research of experts and scholars. Research and innovation have promoted the development of deeper and broader fields in both directions. Especially through the study of foreign cases, it provides reference for the state to formulate industrial policies and technical standards.

This paper is organized as follows: Section 1 describes the research background of the coupling between Chinese automotive industry and information technology industry and the main structure of this paper; Section 2 introduces the current situation of foreign research in related fields and summarizes the research significance of this paper; Section 3 examines the coupling relationship between Chinese automotive industry and information technology industry and establishes a model for evaluating the innovation capability of automotive industry based on gray correlation space; Section 4 investigates the degree of industrial coupling based on the coupling development model and Section 5 summarizes the research content of this paper and provides an outlook on the future research direction.

2. The Related Works

Coupling originally belongs to the category of physics, refers to two or more systems through the interaction of the formation of mutual influence and even the phenomenon of mutual union, in recent years has been constantly introduced to the economic disciplines, and refers to the role of certain conditions, two economic phenomena combined and the role of objective phenomena [9]. Industry experts believe that industrial coupling refers to the economic phenomenon that two or more systems composed of two or more types of industries of different nature, through their respective coupling elements, produce mutual effects and influence each other [10]. By definition, compared with industrial integration, industrial coupling focuses more on the way of connection and the degree of association between multiple industrial subjects. Everything in the world is universally connected, and all industries are no exception, and all have different degrees of connection [11]. According to the viewpoint of the industrial economics, industrial association is the basis of industrial coupling, and when industrial coupling develops to a certain stage, industrial integration and agglomeration will appear. Industrial integration mainly occurs within the industry, while industrial coupling is more inclined to the association between different industrial subjects, and all three contribute to the formation of new industrial ecology [12].

Some studies have found that between industrial development and regional industrial structure, the two have a high degree of coupling, and scientific and technological innovation and industrial structure upgrading are the focus of their mutual coupling, and the goal of coupling is achieved through the internal network system of industry with the support of various external forces [13]. Some researchers believe that the coupling development of strategic emerging industries and traditional industries plays an important role in the construction of the modern industrial system, the improvement of international competitiveness, and the realization of economic transformation [14]. In addition, there are also studies that strategic emerging industries and traditional industries have an interactive relationship, with the former needing the promotion of the latter at the early stage of development and the transformation and upgrading of the latter needing the drive of the former [15].

China’s automobile industry is characterized by relative fragmentation and small scale, and the coupling relationship is not obvious. This thesis argues that before 2010, the coupling phenomenon between the automotive industry and other industries was not obvious. However, in the past five
years, the information technology industry represented by the Internet has created a strong connection with the three industries, and the phenomenon of “Internet+” has emerged, and this coupling trend is reshaping each industry. In the automotive industry, the emergence of the Internet of Vehicles has made this coupling even more significant. Since the coupling between the Internet and the automotive industry needs to span multiple disciplines, there are few research results in this area, which will be the focus of this thesis.

After more than half a century of development, information technology has developed to a new height represented by the Internet of Things, big data, and cloud computing; especially the Internet of Things, able to use radio frequency identification, infrared sensors, global positioning systems, laser scanners, and other information sensing devices and able to connect any object to the Internet according to the agreed protocol, for information exchange and communication, is the latest form of presentation and technology of today’s era application.

In terms of the association and interaction between two or more industries, many experts and scholars have done very much research in the fields of industrial integration and industrial agglomeration, whose research history has been more than half a century and has formed a more complete theoretical system and school of thought. For example, the division of labor theory of Adam Smith, Marx, Marshall, and Allan Younger has become the basic theory of industrial integration. After that, the industrial zone theory represented by Marshall, the new economic geography theory represented by Krugman, the agglomeration economy theory represented by Weber, the growth pole theory represented by Pelou, and the competitive advantage theory represented by Porter gradually formed the theoretical system of industrial clusters. In the era of Industry 3.0, various experts and scholars have made a more positive contribution to the development of industrial interaction theory by practicing the government in industrial park planning and cooperative development. However, in the context of Industry 4.0, the interaction between industries has developed to a new stage, which is no longer limited to agglomeration and integration, especially the development of industrial ecology, which makes the phenomenon of industrial coupling more and more obvious, and the research in this area is still in the initial stage, this paper makes use of the knowledge and theories of cross-disciplinary disciplines to discuss industrial coupling in detail, and to a certain extent, it also makes up for the industrial coupling in terms of theory. It contributes to the formulation of industrial policy, industrial planning and development, and the development of industrial subjects.

In addition, due to the existence of technical and information asymmetry, in the process of penetration of the automotive industry and information technology industry into each other’s fields, there is a situation that each has little understanding of the other’s industrial barriers, depth, and scale, resulting in the phenomena of low coupling speed and quality, and the core advantages of both sides cannot achieve accurate coupling. This paper focuses on how the automotive industry can use the information technology industry to achieve transformation and upgrading and how the information technology industry can realize new industrial ecology such as vehicle networking on the basis of the automotive industry, based on the whole product life cycle theory and the path of system life cycle management, through a deep study of the automotive industry in terms of product characteristics, manufacturing mode, management level, and information technology system. The coupling quality between automotive industry and information technology industry is more excellent and can find the practical path for automotive enterprises to realize intelligent manufacturing in Industry 4.0 era by relying on system lifecycle management.

### 3. Evaluation of Innovation Capability of Automobile Industry Based on Gray Correlation Space

By the 1930s, the automobile industry was booming, and in addition to being sold in the market, automobile products were gradually entering the global market, and the competition between each other was moving from a market to a multibody competition in the international market. In 1953, Toyota Motor, born in 1933, created the Lean Production model with the starting point of continuously eliminating waste and oriented to pull demand. In essence, the lean production mode has not changed the assembly line production mode. Lean production mode has made considerable improvements in the organization and supply mode of production resources, which has made a great leap in the assembly line production mode as a whole. The automobile manufacturing under lean production mode is shown in Figure 1.

According to a report released by the Sadie Research Institute, in 2021, the Information Technology Development Index (IDI), which reflects the overall level of China’s information technology development, will be 66.56, up 5.86 from 60.7 in 2020, of which the Network Readiness Index (NRI), which reflects the maturity of effective information and communication technologies, will be 60.94, up 10.05; the Information and Communication Technology Application Index will be 69.38, up 3.05; and the Application Effectiveness Index will be 72.19, up 3.11. 69.38, an increase of 3.05; the application effectiveness index is 72.19, an increase of 3.11. The comparison of the national informatization development index from 2020 to 2021 is shown in Figure 2.

Industrial development is a dynamic process and is driven by both internal and external factors. External factors are conditions that can promote or hinder the direction of industrial development and transformation quality; internal factors are driving forces that can determine the speed and form of industrial development and are induced by the external conditions. Whether the coupling of automobile industry and information technology industry can be successful depends most on the innovation ability of the automobile industry itself. This section uses gray theory and
related models to construct a dynamic evaluation model of industrial association in order to reveal the process of innovation and problems faced by the automotive industry and finally provide a feasible basis for determining the coupling path between the automotive industry and the information technology industry.

Before determining the coupling path between the automobile industry and the information technology industry to provide a feasible basis, the automobile industry still faces some innovation processes and problems. (1) Technological forces are scattered, and the industrial innovation system has not yet been formed. The innovation system of China’s automobile industry is not perfect. (2) Insufficient funds and narrow source channels. The progress of automobile technology inevitably requires certain scientific research funds, and there are not enough scientific research funds. (3) The awareness of independent brand building in the automotive industry is not strong. The automobile industry is one of the important driving forces to promote the scientific development of the national economy. Countries all over the world are committed to strengthening the control of the automobile industry.

Industrial innovation is the process of industrial development, in order to break through the original constraints and bottlenecks, to form new industrial ecological advantages, and to continuously achieve industrial value improvement. In terms of the automotive industry alone, the innovation content of the automotive industry is a process from market demand to concept product launch and from new product production to market sales. Compared with other industries, the innovation process of the automobile industry has both commonality and individuality. The commonality is mainly reflected in the stage of management innovation and technological innovation, and the individuality is mainly reflected in the stage of conceptual innovation and product innovation. The main contents of industrial innovation are shown in Figure 3.

Fundamentally, industrial innovation is the creative destruction of the original industrial structure and the formation of a new technology or a brand new industry based on it, or the complete transformation of the original industry. The degree of industrial innovation depends on the scale of inputs, among which, the most important inputs include capital, human resources, and technology.

The scale and speed of capital investment are directly and positively related to the efficiency of industrial innovation. In terms of the main body of capital investment, it mainly includes enterprises, government, individuals, financial...
institutions, etc.; in terms of the direction of capital use, it includes support, incentive, and orientation, etc. The capital investment in industrial innovation has greater risk; therefore, many enterprises are willing to adopt the following strategy. The primary factor in promoting innovation is the support of decision-makers. The fundamental purpose of innovation is to find the best solution to solve practical problems. The attention of decision makers to innovation is the driving force for enterprises to actively participate in the search for the best solution. The concern and encouragement of leaders are the direct manifestations of supporting innovation. However, the continuous investment, risk, and unpredictability of innovation make the decision-makers support for innovation often unable to persevere. Manpower is the implementer of industrial innovation activities and the supporting factor of technological innovation, and industrial innovation objects generally belong to high-end technology fields. Therefore, the level of human elements invested in industrial innovation activities, especially the technical talents with high innovation ability, plays an important role in the formation of the realization of industrial innovation activities. Therefore, the government and enterprise sectors should do a good job of introducing and cultivating high-end talents. The technology element has been the most critical element in any industrial innovation process. The breakthrough and application of one or more new technologies will often give birth to a brand new industrial ecosystem, and because the technology has core value and needs strict confidentiality, it will cause the problem of repeated technological innovation due to the asymmetry of information. It can be seen that in the process of industrial innovation, the establishment of technology and information exchange and trading platforms will be particularly important.

Grey system is a solution to the problem of uncertainty with no experience and little data proposed by Deng Julong in the late 1970s and early 1980s, compared with probability theory which studies "large sample uncertainty" and fuzzy theory which studies "cognitive uncertainty." Compared with probability theory, which studies "large sample uncertainty," and fuzzy theory, which studies "cognitive uncertainty," gray theory focuses on "minority uncertainty." At present, the content of gray theory research mainly includes gray mathematics, gray modeling, gray generation, gray analysis, gray prediction, gray decision making, gray control, etc. Among them, the gray analysis generally refers to gray analysis. Among them, the gray analysis generally refers to gray correlation analysis, the purpose of which is to establish a gray correlation analysis model, quantify and order the correlation factors, and then form comparability.

From the perspective of industrial organization, the automobile industry is now closely coupled with new industries such as the Internet, and it is in the moderate coupling stage; therefore, there are relatively little data related to industrial coupling, and there is uncertainty about the depth and degree of coupling. In addition, because the perception of the use experience and product quality of automotive products is usually influenced by many known and unknown or nondeterministic factors such as consumers’ tastes, habits, and use environment, it also has typical gray system characteristics. Therefore, through the gray correlation analysis method, factors with a high degree of association with the automotive industry can be derived, which in turn can help the transformation and upgrading of the automotive industry and further build a system lifecycle management system.

The calculation steps of the gray correlation model are as follows.

3.1. Determining the Series to Be Analyzed. Collect overall data, and categorize accordingly, the data series reflecting the characteristics of the behavior of the subject of the examination identified as the reference series, and the data series consisting of factors affecting the behavior of the subject of the examination identified as the comparison series.

Let \( \omega \) be the original sequence,

\[
\omega = (\omega(1), \omega(2), \ldots, \omega(n)),
\]

\[\forall \omega(k) \in \omega \Rightarrow k \in K = \{1, 2, \ldots, n\}.\]
3.2. Dimensionless All Variables. Considering the accuracy of the analysis results, it is necessary to deal with the data dimensionless in the grey correlation analysis because the selected data may have different amplitudes.

\[ x_i(k) = \frac{\omega_i(k)}{\omega_i(l)}, \quad k \in K = \{1, 2, \ldots, n\}. \]  

(2)

3.3. Calculating the Number of Correlation Coefficients. The number of correlation coefficients is calculated as follows:

\[ \gamma(x_0(k), x_i(k)) = \frac{\xi_{\text{max}} \Delta_{x_0}(k) - \Delta_{x_i}(k) - \xi_{\text{max}} \Delta_{x_0}(k)}{\Delta_{x_i}(k) + \xi_{\text{max}} \Delta_{x_0}(k)}, \]  

(3)

where \( \xi \) is called the correlation coefficient, also known as the resolution coefficient, and usually the value range of \( \xi \) is \((0, 1)\); in practice, its specific value depends on the situation. It is generally accepted that there are two representations of the magnitude of the resultant values:

1. The smaller the \( \xi \), the greater the resolution
2. The resolution is best when \( \xi \leq 0.5463 \) is used, which is usually taken as \( \xi = 0.5 \)

3.4. Calculation of the Correlation between Elements. The correlation coefficient is a direct representation of the correlation degree between the comparison series and the reference series in the selected time period, and its average value is obtained and used as a quantitative representation of the correlation degree between the comparison series and the reference series, which is calculated by the following formula:

\[ \gamma(x_0, x_1) = \frac{1}{n} \sum_{k=1}^{n} \gamma(x_0(k), x_1(k)). \]  

(4)

3.5. Sorting by Correlation Value. The correlations are ranked by the magnitude of the values and analyzed accordingly to the actual situation.

The industrial innovation path runs through the four systems of subject, content, input, and output. According to the SMART principle, the government, universities and research institutes, and enterprises are selected as industrial innovation main body indicators; products, management, and technology are selected as industrial innovation content indicators; capital, manpower, and technology industrial innovation are selected as input indicators; new products, new industries, and new ecology are selected as industrial innovation output indicators, and the evaluation of industrial innovation capability is constructed according to the principles of quantification, comparison, and representation.

According to the principles and requirements of the grey correlation analysis method, reference data columns should be determined first. Based on the availability of innovation data in China’s auto industry, the new product output value is selected as the reference data column for the grey correlation analysis, the quantitative indicators of the other three dimensions are taken as the comparative data column, and the grey correlation model is used to calculate to determine the value and correlation of each element in the innovation process of the auto industry. The correlation score of industrial innovation is shown in Figure 4.

In the automotive industry, the sales volume of automobiles is the core indicator for evaluating the performance of the automotive industry. Therefore, according to the research area and content of this thesis, the value added of the automotive industry is selected as a characteristic indicator of the innovation output of the industry and as a basis for calculating and analyzing the degree of interconnection in the innovation process of the automotive industry.

According to the analysis results, the comprehensive correlation between industrial innovation input and industrial innovation results is the strongest, with a correlation degree of 0.83645, and among the two indicators of industrial innovation input, capital, and talent, the correlation degree of capital reaches 0.9372 and ranks first in the ranking of all indicators. The calculation result of the grey correlation model shows that the highest correlation degree with the value added of the automobile industry is the degree of capital investment in industrial innovation input. The level of industrial innovation investment of an enterprise can directly reflect the competitiveness of an enterprise, so enterprises should consider industrial innovation as the life of an enterprise and invest heavily in industrial innovation activities.

R&D intensity is a basic indicator to examine an enterprise or a country’s investment in R&D, mainly examining the proportion of research and development expenses in sales revenue. From the perspective of R&D intensity, the average R&D intensity of China’s 14 vehicle enterprises is 2.86, which is just higher than that of South Korea and India and much lower than that of the United States, Germany, France, and Japan. The R&D intensity of the automobile industry in major countries in the world in 2020 is shown in Figure 5.

Thus, if the Chinese auto industry wants to rise to the top, it needs to invest more in R&D, especially in basic components, to build a foundation for the overall improvement of auto quality. Through the analysis of the industrial innovation correlation model, it can be seen that the industrial innovation content ranks second with a correlation score of 0.77886, among which “management innovation” ranks second with a correlation score of 0.876. Meanwhile, “technology level” ranks second in the category of industrial innovation content with a correlation score of 0.8659 and third in the ranking of correlation with industrial innovation results. In this indicator of industrial innovation content, the human factor is mainly highlighted. People are the most basic element of all social and economic activities. The performance level of various activities of industrial innovation directly depends on the enterprise’s investment in technology R&D personnel, while the management level
of key and core talents can directly reflect the enterprise’s management ability.

The industrial innovation correlation model shows that the correlation between industrial innovation performance and industrial innovation output is 0.7458, ranking third. Among them, the new product aspect, which is the most central, has the highest correlation of 0.8264, ranking fifth among all the correlation indicators. Despite the late start of the Chinese auto industry, the improvement of product quality in the Chinese auto industry can be basically divided into three levels, one of which is the independent car enterprise represented by Great Wall Motor, which continuously improve their product sequence and quality in the baptism of the market; the second is the enterprises such as FAW and SAIC, which use new technologies and continuously improve product quality in their own brands through borrowing from joint ventures; the third is the enterprises represented by Geely. The third is to acquire technology and improve product quality directly through acquisition by enterprises represented by Geely and BAIC. But no matter which forms, they have achieved very good results.

According to the calculation results, the score of the industrial innovation main body is 0.7399, which is located in the fourth place among the four major categories of indicators, among which the correlation between universities and research institutes is located in the first place in this indicator and in the fourth place in the overall indicator. This indicates that universities and research institutes have a very important position in industrial innovation output by virtue of their monopolistic characteristics in the cultivation of innovative talents.

4. Research on the Development Capacity of Industrial Coupling Based on AHP Method and Dephi Method

Industrial integration aims at the emergence of new industries or new growth points and refers to the dynamic
process of mutual influence, mutual penetration, crossover, and eventual integration into one or formation of new industries between different industries within the same industry or between different industries driven by certain common interests or goals. Compared with industrial integration, the industrial coupling is the cooperative use and interaction between different industries or subsystems within industries in the market, production factors, product development, technological innovation, and other aspects. It can be seen that the mutually coupled industries will not be affected by industrial integration, and there are similarities and differences between the two at the same time. Through industrial coupling, it can promote the maximization and optimization of resource utilization efficiency and help the formation of the new industrial system under the induction of certain environment and technology. Therefore, the study of using coupling theory to explain industry in structural adjustment and transformation and upgrading is adapted to the need for structural adjustment and transformation and upgrading of China’s current automobile industry in the context of Industry 4.0.

Let there be $n$ factors in a layer, $X = \{x_1, x_2, \ldots, x_n\}$, to compare their degree of influence on a criterion (or goal) in the upper layer and thus determine the weight in that layer relative to a criterion (i.e., ranking the degree of influence of $n$ factors on a goal in the upper layer).

The above comparison is a comparison between two factors, and the comparison result (scale) of the $i$-th factor relative to the $j$-th factor is denoted by $a_{ij}$, and then the matrix $A$ is noted as a pairwise comparison matrix, with

$$A = (a_{ij})_{n \times n} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix},$$

$$a_{ij} = \frac{1}{a_{ji}}.$$  \hspace{1cm} (5)

That is, the pairwise comparison matrix $A$ is a positive and negative matrix.

The importance ranking of the evaluation aspects of the automotive industry is as follows: $W_1 > W_5 > W_5 > W_4 > W_2$. Therefore, the comparison matrix of the evaluation aspects of the automotive industry is

$$W = \begin{pmatrix} 1 & 7 & 3 & 5 & 2 \\ \frac{1}{7} & 1 & 1 & 1 & 1 \\ \frac{1}{3} & 1 & \frac{3}{2} & 2 & 4 \\ \frac{1}{3} & 3 & 1 & 2 & \frac{1}{2} \\ \frac{1}{5} & 2 & 1 & \frac{1}{2} & \frac{1}{3} \\ \frac{1}{2} & 4 & 2 & 3 & 1 \end{pmatrix}. \hspace{1cm} (6)$$

For the economic benefits $W_1$, the order of importance is $B > A$, so the comparison matrix under economic benefits is

$$W_1 = \begin{pmatrix} 1 & 1 \\ \frac{1}{2} & 1 \end{pmatrix}. \hspace{1cm} (7)$$

For the development potential of $W_2$, the order of importance is $C = D$, so the comparison matrix under development potential is given by

$$W_2 = \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}. \hspace{1cm} (8)$$

For industry performance $W_3$, the importance ranking is $F > E$, so the comparison matrix under industry performance is given by

$$W_3 = \begin{pmatrix} 1 & \frac{1}{3} \\ 3 & 1 \end{pmatrix}. \hspace{1cm} (9)$$

For industry competitiveness $W_4$, the importance ranking is $G > H > I$, so the comparison matrix under industry competitiveness is given by

$$W_4 = \begin{pmatrix} 1 & 2 & 4 \\ \frac{1}{2} & 1 & 2 \\ \frac{1}{4} & \frac{1}{2} & 1 \end{pmatrix}. \hspace{1cm} (10)$$
The evaluation index parameters of coupled development of automobile industry are shown in Figure 6. Figure 7 shows the evaluation index parameters of information technology industry coupling development. The evaluation of the coupling development capacity of the automobile industry is shown in Figure 8. The evaluation of the coupling development capacity of the information technology industry is shown in Figure 9.

The final result is

\[ W = 1.284284896 \approx 1.28, \]
\[ U = 0.94514528 = 0.95. \]  

Coupling correlation:

\[ C = \sqrt{\frac{U \times W}{(U + W)^2}} = 0.49. \]  

Coupled sustainability model:

\[ D = \sqrt{C \times T} = \sqrt{C \times (a \times U + b \times W)}. \]  

Objective: 0.70–0.79 moderately developmental, so take \( a = 0.5, b = 1 - a = 0.5 \), which gives \( D = 0.74 \).

According to the criteria when \( C = 0 \), it means that there is no coupling between the automotive industry and information technology industry; when \( 0 < C \leq 0.3 \), it means that the coupling between the automotive industry and information technology industry is low and in the growth stage; when \( 0.3 < C \leq 0.7 \), it means that the coupling between the automotive industry and information technology industry is moderate and is in the early stage of development; when \( 0.7 < C < 1 \) it means high coupling between the automotive industry and information technology industry, which is in the middle and late stage of development; according to the calculation results of this thesis, it is concluded that the coupling correlation between the automotive industry and information technology industry reaches 0.49, which means that automotive industry and information technology industry are currently in the moderate coupling stage and are in the early stage of development. From the practical point of view, the correctness of the results is also verified.

Although the coupling correlation degree can reflect the degree of coupling between the automotive industry and the information technology industry to a certain extent, it does not reflect the development level and trend of the two in general. According to the calculation results of this thesis, it is concluded that the coupling continuity development degree between the automotive industry and the information technology industry reaches 0.74, which indicates that the automotive industry and the information technology industry are currently at a moderate development stage. After a short period of time, the two will definitely enter into a good development type stage. Therefore, as an automotive company, it should take the initiative to couple with information technology companies, especially in the technology related to mobile Internet, to keep up with the times.

For the market performance \( W_5 \), the importance ranking is \( J = K \), so the comparison matrix under economic efficiency is given by

\[
W_5 = \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}. \tag{11}
\]

Importance ranking of IT industry evaluation aspects is \( U_2 > U_1 > U_3 > U_4 \). Therefore, the comparison matrix of IT industry evaluation aspects is given by

\[
U = \begin{pmatrix} \frac{1}{2} & 2 & 1 & 3 \\ 2 & 1 & 3 & 5 \\ \frac{1}{2} & 3 & 1 & 3 \\ \frac{3}{5} & \frac{1}{5} & \frac{1}{3} & 1 \end{pmatrix}. \tag{12}
\]

For the level of development of IT industry \( U_1 \), the order of importance is \( M > L \), so the comparison matrix under the level of development of IT industry is

\[
U_1 = \begin{pmatrix} 1 & \frac{1}{2} \\ 2 & 1 \end{pmatrix}. \tag{13}
\]

For the economic benefits \( U_2 \), the order of importance is \( P > O > N \), so the comparison matrix under economic benefits is given by

\[
U_2 = \begin{pmatrix} \frac{1}{2} & 1 & \frac{1}{4} \\ 2 & \frac{1}{2} & 1 \\ 4 & 2 & 1 \end{pmatrix}. \tag{14}
\]

For the development potential of \( U_3 \), the order of importance is \( R > Q \), so the comparison matrix under development potential is

\[
U_3 = \begin{pmatrix} 1 & \frac{1}{3} \\ 3 & 1 \end{pmatrix}. \tag{15}
\]

For the competitive power \( U_4 \), the order of importance is \( T > S \), so the comparison matrix under the competitive power is given by

\[
U_4 = \begin{pmatrix} \frac{1}{2} \\ 2 & 1 \end{pmatrix}. \tag{16}
\]
Figure 6: Evaluation index parameters of the coupling development of the automobile industry.

Figure 7: Information technology industry coupling development evaluation index parameters.
5. Summary and Outlook

This paper focuses on the current situation of China’s automotive industry, using data for analysis and prediction, considering the level of development of China’s automotive industry, the gap with foreign automotive industries, etc. The aim is to conduct an empirical study on the possibility of coupling, degree of coupling, degree of association, and innovation capability of China’s automotive industry and information technology industry through the research in this chapter. This paper starts with an overview analysis of the development of China’s automotive industry and information technology industry through the research in this chapter. This paper starts with an overview analysis of the development of China’s automotive industry and information technology industry. Then, we use gray correlation analysis to discuss the factors influencing the innovation of China’s automotive industry and find that the capital investment in “industrial innovation investment” has the most significant relationship with it. Finally, a coupling development model between the automotive industry and the information technology industry was established, and the degree of coupling between the two was analyzed using the AHP and Dephi methods. After calculation, it was found that the degree of correlation between the two reached 0.49, indicating that the automotive industry and the information technology industry are at a medium development stage, indicating that the coupling between the automotive industry and the information technology industry is in line with the industrial development trend.

In terms of the research content of this paper, not many experts and scholars have studied the interaction between two or more industries from the perspective of integration. This thesis is a pioneering study on the relationship between the coupling development of the automotive industry and the information technology industry, and if an extended study can be conducted from the perspective of enterprise strategy, it can also provide greater help to the development direction and ideas of automotive and information technology enterprises. Since the research of this paper is mainly focused on the automobile industry, under the Internet tide, other industries such as the commerce and service industry also have a strong coupling relationship with the information technology industry, which will provide a new research direction for the subsequent research of experts and scholars. However, there are still some deficiencies in this paper. The research on the external factors affecting the coupling development relationship between the automobile industry and information technology industry is not enough. It would be better if extended research could be carried out from the perspective of different environments. Although the coupling correlation degree can reflect the coupling degree of the automotive industry and information technology to a certain extent, it cannot reflect the development level and trend of the two industries as a whole. This needs further analysis in the future development.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known conflicts of financial interest or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was supported by Youth Project of High-End Technology Innovation Think Tank: Research on the Construction of New Industrial Infrastructure and Industrial Digital Upgrade (no. 2021ZZZLFZB1207116).

References


[8] Science - Social Science, “New social science data have been reported by researchers at technical university valencia (TU valencia) (impact of digital transformation on the automotive industry),” *Journal of Transportation*, 2020.


