

## Research Article

# Cost-Benefit Models on Integrating Information Technology Services in Automotive Production Management

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The integration of the new-generation information technology and the automobile manufacturing industry has significantly improved the production efficiency of the automobile manufacturing industry, but it will also increase the technology application cost of the automobile manufacturing industry. The boundary value of the income change of the automobile manufacturing industry can be obtained by examining the influence of new-generation information technology on the price of parts, the price of automobiles, and the quantity of production in the upstream and downstream of the automobile manufacturing industry chain. The study found that the benefit of the automobile manufacturing industry that meets the conditions of technology application costs has increased. The value added to the downstream enterprises in the industrial chain is greater than the value added to the upstream companies. The lower the cost of technology application, the greater the impact on the number of automobile production. In the end, an example is used to verify the reliability of the research results.

## 1. Introduction

Nowadays, a new round of scientific and technological revolution which is represented by big data analysis, mobile Internet of Things, cloud computing, etc., is sweeping the world. A new manufacturing system of interconnection, capability collaboration, resource sharing, and open cooperation is being built, which greatly expands the space for innovation and development of the manufacturing industry. As an important support of China's industrial economy, the automobile manufacturing industry is characterized by a large number of parts, long industrial chains, and large-scale and complex production organizations. It is closely related to other industries and plays an important role in leading economic growth. The development of the new-generation information technology will drive China's automobile manufacturing industry to a new stage of transformation and upgrading. Under the role of the new-generation information technology, the entire industrial chain, the entire production process, and the entire manufacturing life cycle of the automobile manufacturing industry have been optimized and

upgraded, which will accelerate the pace of China's transformation from a big automobile manufacturing country to a powerful automobile manufacturing country. The upstream of the automobile manufacturing industry chain is automobile parts manufacturing enterprises, and the downstream is automobile manufacturing enterprises. The integrated development of the new-generation information technology and automobile manufacturing industry will optimize the production mode of the automobile manufacturing industry chain, improve the industrial chain interaction mode, and bring new economic growth points [1]. Under the guidance of the "Made in China 2025" action plan, the whole industry chain of automobile manufacturing will be deeply integrated and applied with the new-generation information technology. The automobile parts manufacturing enterprises will achieve the refined production, the automobile manufacturing enterprises will achieve the intelligent manufacturing, and the whole industry chain will achieve the real-time interconnection and intelligent logistics and jointly promote the transformation and upgrading of the automobile manufacturing industry [2].

## 2. Literature Review

The deep integration of new-generation information technology and manufacturing makes the development of manufacturing and the innovation of science and technology present unprecedented features and trends. Based on the application of new-generation information technology, the manufacturing industry will achieve digital, networked, and intelligent manufacturing, which will have a profound impact on the high-quality development of Chinese manufacturing [3, 4]. Thirupathi and Vinodh [5] took auto parts manufacturing enterprises in southern India as an example, and a structural equation model was established to study the importance of sustainable manufacturing for auto parts manufacturing companies to maintain a competitive advantage and analyze the relationship between the sustainable development factors of auto parts manufacturing companies. Huang and Zhang [6] used the gray correlation analysis and analytic hierarchy process to establish the hierarchical structure model of the multiangle indices system of the supply chain management of the automobile manufacturing industry, proposed that efficient supply chain management and the application of information technology have a significant impact on the economic efficiency of automobile manufacturing companies. Li et al. [7] proposed that the manufacturing industry is moving towards smart manufacturing through new-generation information technology. The deep integration and development of new-generation information technology and manufacturing would lead to the innovation of manufacturing methods, organizational forms, and manufacturing models in the manufacturing industry, thereby promoting the transformation and upgrading of the manufacturing industry. Tao et al. [8] believed that the integration of new-generation information technology and manufacturing can promote manufacturing to achieve manufacturing collaboration, product design personalization, service management customization, and system resource integration, which would help manufacturing achieve smart manufacturing and create higher economic value. Cainelli et al. [9] conducted empirical research on Spanish manufacturing companies and found that manufacturing companies continue to carry out innovative R&D activities with the help of new-generation information technology, which would help manufacturing achieve intelligent manufacturing. From the perspective of the application of information technology, Liu and Gu [10] deeply analyzed the development process of advanced manufacturing and the application of information technology. He found that information technology has an important impact on the manufacturing process and manufacturing technology, and the key to the transformation and upgrading of the manufacturing industry lays in the integrated application of information technology.

In summary, the research on the integration of new-generation information technology and the automobile manufacturing industry is gradually accumulating, and the research of more experts and scholars is mainly distributed in the significance of the integration of new-generation information technology and the manufacturing industry. There are few specific studies on how the automobile

manufacturing industry applies new-generation information technology and the specific impact path of new-generation information technology on the automobile manufacturing industry, and this kind of study precisely determines whether the automobile manufacturing industry integrates and applies new-generation information technology. This article starts from the automobile manufacturing industry chain and analyzes the costs and benefits of the automobile parts manufacturing industry located upstream of the industry chain and the vehicle manufacturing industry located downstream of the industry chain. This paper will focus on comparing the impact on the automobile manufacturing industry before and after the application of new-generation information technology and guide the integration of new-generation information technology and automobile manufacturing.

## 3. Model Assumptions and Design

The automobile manufacturing industry chain includes upstream automobile component manufacturing and downstream vehicle manufacturing. The automobile component manufacturing industry uses material resources to produce components suitable for automobiles and deliver them to the downstream vehicle manufacturing industry [11]. The vehicle manufacturing industry uses the supplied parts to produce passenger cars or freight cars for the market [12]. Automobile manufacturing companies need to purchase parts from auto parts manufacturing companies at a price  $b$  to manufacture  $q$  number of cars. Auto parts manufacturing companies determine auto parts shipments and prices based on their manufacturing costs and logistics costs. After receiving the parts and components, the automobile manufacturing enterprise carries out manufacturing. Automobile manufacturers determine the market sales price of automobiles  $P$  based on market demand, processing and manufacturing costs, logistics costs, and advertising effectiveness.

### 3.1. Model Assumptions

**3.1.1. Logistics Costs.** In the automobile manufacturing industry chain, supposing that the logistics cost of transporting material resources for the production of parts by the auto parts manufacturing company is borne by the auto parts manufacturing company, which is  $c_1(t)$ . The logistics cost of auto parts manufacturing enterprises to deliver parts to auto manufacturing enterprises is borne by auto manufacturing enterprises, which is  $c_2(t)$ . The logistics cost function is positively related to transportation time. The longer the transportation time, the higher the logistics cost that needs to be paid [13]. Therefore, assuming that the logistics cost function is a function with transportation time as an independent variable, some of the characteristics of the function are  $\partial c_1(t)/\partial t \geq 0$  and  $\partial c_2(t)/\partial t \geq 0$ .

**3.1.2. Manufacturing Costs.** The manufacturing cost of the automobile manufacturing industry includes the rental fee of the production workshop, the salary of labor workers, the

depreciation of production equipment and machinery, and other expenses in the manufacturing process [14]. Assuming that the manufacturing cost of the process of producing and processing auto parts for the auto parts manufacturing enterprise is  $\alpha_1(t)$ , the manufacturing cost of auto manufacturing companies using resources such as parts and components to produce a car is  $\alpha_2(t)$ . There is a positive correlation between manufacturing costs and time spent. The longer the time required for manufacturing, the higher the salary the enterprise needs to pay for workers, and other costs incurred in manufacturing increase with time, and the higher the manufacturing cost. Therefore, assuming that the manufacturing cost is a function of the required time as an independent variable, some features of the function are  $\partial\alpha_1(t)/\partial t \geq 0$  and  $\partial\alpha_2(t)/\partial t \geq 0$ .

**3.1.3. Material Costs and Other Costs.** The automobile manufacturing industry requires a certain amount of materials when manufacturing products. Assuming that material costs and other costs are  $a$ , they are jointly borne by the automobile parts manufacturing company and the automobile manufacturing company. The decision-makers in the operation and management of the automobile manufacturing industry are completely rational, and the risk appetite is neutral.

**3.1.4. Advertising Marketing Effect.** To increase the sales volume of automobiles and expand the scale of market demand, automobile manufacturers will actively put advertisements on the market to promote the popularity of automobile brands, so that let potential consumers in the market have a good impression on the brand car, stimulate consumers' desire to buy, and help the brand car open the market [15, 16]. After applying new-generation information technology, Internet propaganda will make the advertising of auto manufacturing companies achieve social marketing effects. Automobile manufacturers use big data analysis technology to build potential customer relationship graphs to fully understand the actual market demand. The cloud computing platform will use targeted data mining to precisely target and deliver targeted advertisements to gain users' goodwill and effectively enhance brand value [17, 18]. Supposing the advertising marketing effect function of automobile manufacturing enterprises is  $\varnothing(t)$  ( $0 \leq \varnothing(t) \leq Z$ ), when  $\varnothing(t) = 0$ , advertisement marketing does not affect; when  $\varnothing(t) = Z$ , advertising marketing is fully effective. The longer the advertising period, the more likely the potential consumers in the market to see this advertisement, and the greater the number of potential consumers who see this advertisement. Therefore, the advertising marketing effect function is a function with time as its independent variable, and some of the features of the function are  $\partial\varnothing(t)/\partial t \geq 0$ .

**3.1.5. New-Generation Information Technology Application Costs.** The integration of new-generation information technology and the automobile manufacturing industry will help to promote the automobile manufacturing industry to complete technological innovation and upgrade, personalized product

design, diversified customer service, and integrated manufacturing. Increased production efficiency will release labor, intelligent logistics will reduce transportation time, and the interconnection of production equipment and machines will realize intelligent manufacturing [19, 20]. The application of new-generation information technology in the automobile manufacturing industry chain has to pay a certain application cost. Assuming that the application cost of new-generation information technology is  $C_{IT} = C_t + C_y$ , where  $C_t$  is fixed and  $C_y$  is a variable cost. The application cost of new-generation information technology is jointly borne by the upstream automobile parts manufacturing enterprises and the downstream vehicle manufacturing enterprises. After applying new-generation information technology, the overall manufacturing efficiency of the automobile manufacturing industry has improved, the logistics time has been shortened, and the advertising and marketing effects have become better and better.

**3.1.6. Demand Function.** The demand of potential consumers in the market for cars is affected by the sales price of cars and the effectiveness of advertising and marketing. With the same price, the better the car advertising effect, the more likely the potential consumers will buy. Based on the research of Abu-Eisheh and Mannering [21] and Yu et al. [22], we can assume that the market's demand function for cars is  $n = AP^{-k}\varnothing(t)$ , where  $A$  is the market size coefficient,  $k$  is the price elasticity coefficient, and  $k > 1$ .

**3.1.7. Cost Function and Benefit Function.** We set the cost function of the automobile manufacturing industry to be represented by  $C_y^x$  and the profit function to be represented by  $L_y^x$ . Among them,  $x \in \{E, F\}$ , where  $E$  stands for automobile parts manufacturing enterprises and  $F$  stands for automobile manufacturing enterprises;  $y \in \{0, 1\}$ , where 0 represents that the automobile manufacturing industry has not applied new-generation information technology and 1 represents that the automobile manufacturing industry has applied new-generation information technology.

Assuming that the time spent without applying new-generation information technology is  $t_1$ , and the time spent by the automobile manufacturing industry after the application of new-generation information technology is  $t_2$ , the logistics cost and manufacturing cost of auto parts manufacturing companies and auto manufacturing companies, respectively, meet  $0 \leq c_1(t_2) \leq c_1(t_1)$ ,  $0 \leq \alpha_1(t_2) \leq \alpha_1(t_1)$ ,  $0 \leq c_2(t_2) \leq c_2(t_1)$ , and  $0 \leq \alpha_2(t_2) \leq \alpha_2(t_1)$ . The advertising marketing performance function satisfies  $0 \leq \varnothing(t_1) \leq \varnothing(t_2) \leq 1$ .

## 3.2. Model Design

**3.2.1. Cost-Benefit Model of Automobile Manufacturing.** Automobile manufacturers purchase parts from auto parts manufacturers at a price  $b_0$  to produce  $q_0$  quantity of cars. The unified assumption of logistics time and manufacturing time is  $t_1$ . The cost of an automobile manufacturing

company is  $C_0^F = [b_0 + \alpha_2(t_1) + c_2(t_1)]q_0 + a$ , and the benefit is  $L_0^F = [p_0 - b_0 - \alpha_2(t_1) - c_2(t_1)]q_0 - a$ . Because the market demand function is  $n = AP^{-k}\varnothing(t)$ , to pursue maximum profits, automobile manufacturers will set appropriate sales prices based on market demand, and then it can be concluded  $P_0 = [A\varnothing(t)/q_0]^{1/k}$ . Substituting this formula into the benefit function yields

$$L_0^F = \left\{ \left[ \frac{A\phi(t_1)}{q_0} \right]^{1/k} - b_0 - \alpha_2(t_1) - c_2(t_1) \right\} q_0 - a. \quad (1)$$

To maximize the profits of the automobile manufacturing enterprise, there must be a suitable  $q_0$  so that the benefit function reaches the maximum value, and obviously, the second derivative of the benefit function is less than zero. If the first derivative of the benefit function is zero, then we have

$$q_0^F = A\phi(t_1) \left\{ \frac{k-1}{k[b_0 + \alpha_2(t_1) + c_2(t_1)]} \right\}^k. \quad (2)$$

Substituting (2) into the price function gives

$$P_0^F = \frac{k[b_0 + \alpha_2(t_1) + c_2(t_1)]}{k-1}. \quad (3)$$

According to this, we can get the cost and benefit of auto manufacturers when the price of parts is  $b_0$ :

$$C_0^F = A\phi(t_1)[b_0 + \alpha_2(t_1) + c_2(t_1)] \left\{ \frac{k-1}{k[b_0 + \alpha_2(t_1) + c_2(t_1)]} \right\}^k + a, \quad (4)$$

$$L_0^F = A\phi(t_1) \left[ \frac{b_0 + \alpha_2(t_1) + c_2(t_1)}{k-1} \right] \left\{ \frac{k-1}{k[b_0 + \alpha_2(t_1) + c_2(t_1)]} \right\}^k - a. \quad (5)$$

The costs and benefits of auto parts manufacturing companies are as follows:

$$C_0^E = [c_1(t_1) + \alpha_1(t_1)]q_0 + a, \quad (6)$$

$$L_0^E = [b_0 - c_1(t_1) - \alpha_1(t_1)]q_0 - a. \quad (7)$$

There is a great value in the benefit of auto parts manufacturing enterprises. Obviously, the second derivative is less than zero, so that the first derivative is zero, and we can get

$$\frac{\partial L_0^E}{\partial b_0} = q_0 + b_0 \frac{\partial q_0}{\partial b_0} - [c_1(t_1) + \alpha_1(t_1)] \frac{\partial q_0}{\partial b_0}. \quad (8)$$

From formula (2), we can get

$$\frac{\partial q_0}{\partial b_0} = q_0 \left[ \frac{-k}{b_0 + \alpha_2(t_1) + c_2(t_1)} \right]. \quad (9)$$

Therefore, the optimal parts prices for auto parts manufacturing companies are as follows:

$$b_0 = \frac{k}{k-1} \left[ c_1(t_1) + \alpha_1(t_1) + \frac{c_2(t_1) + \alpha_2(t_1)}{k} \right]. \quad (10)$$

It can be seen that the price of auto parts will affect the number of cars produced. The lower the price of parts and components, the more cars are produced, and the higher the price of parts and components, the fewer cars are produced. The price of parts is related to the logistics cost and manufacturing cost of auto parts manufacturing companies and auto manufacturing companies. The higher the logistics cost and manufacturing cost, the higher the price of parts.

Substituting equation (10) into equations (4) and (5) can further obtain the specific expressions of the cost and benefit of automobile manufacturing enterprises:

$$C_0^F = \left( \frac{k-1}{k} \right)^{2k-1} A\phi(t_1) [c_1(t_1) + \alpha_1(t_1) + \alpha_2(t_1) + c_2(t_1)]^{1-k} + a, \quad (11)$$

$$L_0^F = \left( \frac{k-1}{k} \right)^{2k-1} \frac{A\phi(t_1)}{k-1} [c_1(t_1) + \alpha_1(t_1) + \alpha_2(t_1) + c_2(t_1)]^{1-k} - a. \quad (12)$$

Substituting equations (2) and (10) into equations (6) and (7), we can obtain the optimal expressions of the cost function and benefit function of the auto parts manufacturing enterprise:

$$C_0^E = \left( \frac{k-1}{k} \right)^{2k} A\phi(t_1) [c_1(t_1) + \alpha_1(t_1)] [c_1(t_1) + \alpha_1(t_1) + \alpha_2(t_1) + c_2(t_1)]^{-k} + a, \quad (13)$$

$$L_0^E = \left( \frac{k-1}{k} \right)^{2k} \frac{A\phi(t_1)}{k-1} [c_1(t_1) + \alpha_1(t_1) + \alpha_2(t_1) + c_2(t_1)]^{1-k} - a. \quad (14)$$

As can be seen from the above model, the costs and benefits of auto parts manufacturing companies and auto manufacturing companies are closely related to logistics costs, manufacturing costs, and advertising and marketing effects. The number of cars produced by automobile manufacturing companies is affected by the price of parts, logistics costs, and manufacturing costs and is directly

proportional to the effectiveness of advertising and marketing. In the development of the automobile manufacturing industry, to reduce costs and increase profits, the logistics costs and manufacturing costs should be controlled as much as possible to improve the production efficiency of the automobile manufacturing industry.

3.2.2. *Cost-Benefit Model of the Integration of New-Generation Information Technology and Automobile Manufacturing.* After the application of new-generation information technology in the automotive industry, the automobile manufacturing industry comprehensively integrates big data, cloud computing, Internet of Things, and other new-generation information technologies in the entire process of R&D, design, management, manufacturing, sales, and service. The construction of intelligent manufacturing capacity in the automobile manufacturing industry chain has been strengthened, the interconnected network system has been improved, and intelligent management and control have been achieved [23]. After applying new-generation information technology, market demand information for automotive products will be effectively communicated to auto manufacturing companies. Automobile manufacturers continue to transmit information to upstream of the industry chain. The auto parts manufacturing company accepts and processes the information and sends the feedback information and an appropriate number of auto parts to the auto manufacturing company [24]. Automobile manufacturers produce automotive products that meet market expectations and put them on the market [25]. The information processing efficiency of this process is improved, logistics time is reduced, manufacturing costs are reduced accordingly, and advertising and marketing effects

are also improved. However, this process requires a certain technical cost to achieve. The application cost of new-generation information technology is jointly borne by the upstream and downstream companies in the automobile manufacturing industry chain.

After bearing the application cost of new-generation information technology, the cost function and benefit function of the auto parts manufacturing enterprise are as follows:

$$\begin{aligned} C_1^E &= [c_1(t_2) + \alpha_1(t_2) + C_t + C_\gamma]q_1 + a, \\ L_1^E &= [b_1 - c_1(t_2) - \alpha_1(t_2) - C_t - C_\gamma]q_1 - a. \end{aligned} \quad (15)$$

According to this, the prices of auto parts manufacturers can be obtained as follows:

$$b_1 = \frac{k}{k-1} \left[ c_1(t_2) + \alpha_1(t_2) + C_t + C_\gamma + \frac{c_2(t_2) + \alpha_2(t_2)}{k} \right]. \quad (16)$$

It can be seen from the above model, in the case of other factors unchanged, the higher the application cost of new-generation information technology, the higher the price of auto parts. Substituting equation (16) into equation (2) can obtain the optimal number of vehicles produced by automobile manufacturing enterprises:

$$q_1^F = \left( \frac{k-1}{k} \right)^{2k} A\phi(t_2) [c_1(t_2) + \alpha_1(t_2) + C_t + C_\gamma + c_2(t_2) + \alpha_2(t_2)]^{-k}. \quad (17)$$

Substituting equation (16) into equation (3), we can obtain the optimal sales price set by the automobile manufacturing enterprise after the application of new-generation information technology:

$$P_1^F = \left( \frac{k}{k-1} \right)^2 [c_1(t_2) + \alpha_1(t_2) + C_t + C_\gamma + c_2(t_2) + \alpha_2(t_2)]. \quad (18)$$

According to (16)–(18), the cost function and benefit function of the automobile manufacturing enterprise can be obtained as follows:

$$C_1^F = \left( \frac{k-1}{k} \right)^{2k-1} A\phi(t_2) [c_1(t_2) + \alpha_1(t_2) + C_t + C_\gamma + c_2(t_2) + \alpha_2(t_2)]^{1-k} + a, \quad (19)$$

$$L_1^F = \left( \frac{k-1}{k} \right)^{2k-1} \frac{A\phi(t_2)}{k-1} [c_1(t_2) + \alpha_1(t_2) + C_t + C_\gamma + c_2(t_2) + \alpha_2(t_2)]^{1-k} - a. \quad (20)$$

The cost function and benefit function of auto parts manufacturing enterprise are as follows:

$$C_1^E = \left( \frac{k-1}{k} \right)^{2k} A\phi(t_2) [c_1(t_2) + \alpha_1(t_2) + C_t + C_\gamma] [c_1(t_2) + \alpha_1(t_2) + C_t + C_\gamma + c_2(t_2) + \alpha_2(t_2)]^{-k} + a, \quad (21)$$

$$L_1^E = \left( \frac{k-1}{k} \right)^{2k} \frac{A\phi(t_2)}{k-1} [c_1(t_2) + \alpha_1(t_2) + C_t + C_\gamma + c_2(t_2) + \alpha_2(t_2)]^{1-k} - a. \quad (22)$$

#### 4. Results

The cost of the automobile manufacturing industry chain is  $C_0 = C_0^E + C_0^F$ , and the benefit is  $L_0 = L_0^E + L_0^F$ . The total cost of the automotive manufacturing industry chain after the integration of new-generation information technology is  $C_1 = C_1^E + C_1^F$ , and the total benefit is  $L_1 = L_1^E + L_1^F$ .

**Theorem 1.** *When  $C_{IT} \leq C_{IT}^T$ , the automobile manufacturing industry's total benefit increases after the application of new-generation information technology.*

*Proof.* The decision-making condition for the automobile manufacturing industry to realize the increase in benefit after the application of new-generation information technology is  $L_1 \geq L_0$ ; combining (20), (22), (12), and (14), we can get

$$C_{IT} \leq \left[ \frac{\phi(t_2)}{\phi(t_1)} \right]^{k-1} [c_1(t_1) + \alpha_1(t_1) + \alpha_2(t_1) + c_2(t_1)] - [c_1(t_2) + \alpha_1(t_2) + c_2(t_2) + \alpha_2(t_2)]. \quad (23)$$

Set the right side of the above formula to  $C_{IT}^T$ , and this value is the boundary of whether the automobile manufacturing industry can improve the profit after the application of new-generation information technology.  $\square$

**Theorem 2.** *When  $C_{IT} \leq C_{IT}^S$ , upstream auto parts manufacturing companies in the automotive manufacturing industry chain will lower the price of parts. When  $C_{IT} > C_{IT}^S$ , auto parts manufacturers will increase the price of parts.*

*Proof.* The decision-making condition for auto parts manufacturing companies to reduce the price of parts after applying new-generation information technology is  $b_1 \leq b_0$ , and combining (16) and (10) and  $k > 1$ , we can get

$$C_{IT} \leq c_1(t_1) + \alpha_1(t_1) - c_1(t_2) - \alpha_1(t_2) + \frac{c_2(t_1) + \alpha_2(t_1) - c_2(t_2) - \alpha_2(t_2)}{k}. \quad (24)$$

Set the right side of the above formula to  $C_{IT}^S$ , and this value is the decision-making boundary for auto parts manufacturers to reduce the price of parts after applying new-generation information technology.  $\square$

**Theorem 3.** *When the application cost of new-generation information technology meets  $C_{IT} \leq C_{IT}^R$ , automobile manufacturers will lower the market sales price of cars and vice versa will increase the selling price.*

*Proof.* The integration and development of new-generation information technology and automobile manufacturing companies have made the decision-making condition for automobile manufacturing companies to reduce car sales prices is  $P_1 \leq P_0$ , and combining (18) and (3), we can get

$$C_{IT} \leq c_1(t_1) + \alpha_1(t_1) - c_1(t_2) - \alpha_1(t_2) + c_2(t_1) + \alpha_2(t_1) - c_2(t_2) - \alpha_2(t_2). \quad (25)$$

Set the right side of the above formula to  $C_{IT}^R$ , and then this value is the boundary value of whether automobile manufacturing enterprises will reduce the sales price of automobiles after applying new-generation information technology.  $\square$

**Theorem 4.** *When the application cost of new-generation information technology meets  $C_{IT} \leq C_{IT}^Q$ , the number of cars produced by automobile manufacturing companies will increase, and otherwise, it will decrease.*

*Proof.* Analyzing the optimal number of cars produced by automobile manufacturing enterprises before and after the application of new-generation information technology (2), (17), and  $q_1 \geq q_0$ , then we can get

$$C_{IT} \leq \left[ \frac{\phi(t_2)}{\phi(t_1)} \right]^{1/k} [c_1(t_1) + \alpha_1(t_1) + \alpha_2(t_1) + c_2(t_1)] - [c_1(t_2) + \alpha_1(t_2) + c_2(t_2) + \alpha_2(t_2)]. \quad (26)$$

Set the right side of the above formula to  $C_{IT}^Q$ , and this value is the basis for the decision of whether to increase the output of automobile manufacturing enterprises after applying new-generation information technology.  $\square$

**Theorem 5.**  $C_{IT}^S \leq C_{IT}^R \leq C_{IT}^Q \leq C_{IT}^T$

*Proof.* Because  $k > 1$ , we can get  $C_{IT}^S \leq C_{IT}^R$ ,  $C_{IT}^Q \leq C_{IT}^T$ . Because  $k > 1$  and  $0 \leq \phi(t_1) \leq \phi(t_2) \leq 1$ , we can get  $C_{IT}^R \leq C_{IT}^Q$ , thus  $C_{IT}^S \leq C_{IT}^R \leq C_{IT}^Q \leq C_{IT}^T$ .

After the application of new-generation information technology in the automotive industry, the greater the improvement in advertising marketing effectiveness, the greater the increase in the benefits of technology upgrades, and the higher the application costs that car manufacturers are willing to bear. The new-generation information technology improves the overall production efficiency of the automotive industry. The lower the logistics cost and manufacturing cost, the greater the technology application cost that the automotive manufacturing industry chain can bear. When the technology application cost is less than  $C_{IT}^S$ , both the price of parts and the price of automobiles have been reduced, and both upstream and downstream enterprises in the automobile manufacturing industry chain have benefited. When  $C_{IT}^S \leq C_{IT} \leq C_{IT}^R$ , auto parts prices rise. In order to develop market demand, automobile manufacturers still sell cars at prices lower than before applying new-generation information technology. When  $C_{IT}^R \leq C_{IT} \leq C_{IT}^Q$ , both auto parts prices and auto selling prices have increased, and the number of auto production has increased. The automobile manufacturing industry tries to transfer the cost of technology application to the market, let consumers share the cost for it, and make the automobile manufacturing

TABLE 1: Impact of the value of  $C_{IT}$  on the automobile manufacturing industry.

		Ranges ( $C_{IT}$ )				
		$[0, C_{IT}^S]$	$[C_{IT}^S, C_{IT}^R]$	$[C_{IT}^R, C_{IT}^Q]$	$[C_{IT}^Q, C_{IT}^T]$	$[C_{IT}^T, +\infty)$
Parameter changes	Parts price	↓	↑	↑	↑	↑
	Auto price	↓	↓	↑	↑	↑
	Number of auto production	↑	↑	↑	↓	↓
	Benefit of the automobile manufacturing industry	↑	↑	↑	↑	↓

TABLE 2: Changes in auto industry’s decision-making parameters.

New-generation information technology	Parts price	Car price	Number of cars produced	Auto parts manufacturing company benefit	Car manufacturing company earnings	The total benefit of the automobile manufacturing industry chain
Before application	23650	81225	51350	$9.27 \times 10^8$	$1.41 \times 10^9$	$2.34 \times 10^9$
After application	22950	65025	278872	$4.00 \times 10^9$	$6.13 \times 10^9$	$1.01 \times 10^{10}$

industry get the most benefits. When  $C_{IT}^Q \leq C_{IT} \leq C_{IT}^T$ , as auto parts prices and auto prices increase, the market’s demand for autos declines, but the benefit can still be improved. When  $C_{IT} > C_{IT}^T$ , the income of the automobile manufacturing industry chain has declined, and it is not recommended to apply new-generation information technology. The relationship between the application cost of new-generation information technology and the benefit of the automobile manufacturing industry is shown in Table 1. □

### 5. Example Analysis

Drawing on the relevant research of experts and scholars [26, 27], according to the data of Chinese automobile manufacturing enterprises, the example parameters are used to verify the model constructed in this paper.

Assuming the scale of demand in the automobile market is  $A = 30000000$ , demand elasticity is  $k = 3$ , the logistics cost of the auto parts manufacturing company is  $c_1(t_1) = 600$ , the manufacturing cost is  $\alpha_1(t_1) = 5000$ ; the logistics cost of the automobile manufacturing company is  $c_2(t_1) = 500$ , the manufacturing cost is  $\alpha_2(t_1) = 30000$ , and the advertising marketing effect is  $\varnothing(t_1) = A^{1.6}$ . In order to promote the technological innovation and upgrade of the automobile manufacturing industry to achieve intelligent manufacturing, it is necessary to integrate and apply new-generation information technology to accelerate its transformation and upgrading process. After the application of new-generation information technology in the automotive industry, the logistics cost of auto parts manufacturing company is  $c_1(t_2) = 500$ , and the manufacturing cost is  $\alpha_1(t_2) = 3500$ ; the logistics cost of the automobile manufacturing company is  $c_2(t_2) = 400$ , the manufacturing cost is  $\alpha_2(t_2) = 20000$ , the advertising marketing effect is  $\varnothing(t_2) = A^{1.66}$ , and the application cost of new-generation information technology is  $C_{IT} = 4500$ . Because material costs and other costs are less affected by new-generation information technology, they will not be included in the example analysis. Substituting the above parameters into the model of this paper, the relationship of the obtained parameters is shown in Table 2.

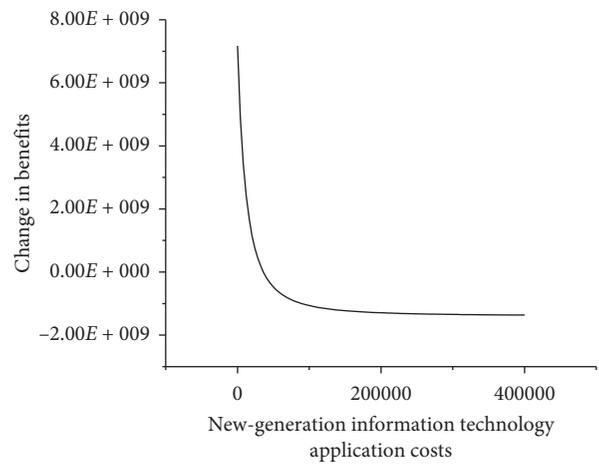


FIGURE 1: Changes in the benefit of the automotive industry.

From Table 1, we can find that when the cost of applying new-generation information technology in the automotive industry is  $C_{IT} = 4500$ , auto parts prices fall by 2.96%, car prices fall by 19.94%, the number of automobile production increases by more than 4 times, and the benefit of auto parts manufacturing companies and auto manufacturing companies have increased by more than 3 times. According to the model, we can also calculate  $C_{IT}^S = 4966.67$ ,  $C_{IT}^R = 11700$ ,  $C_{IT}^Q = 26414.36$ , and  $C_{IT}^T = 259974.14$ , and these satisfy the boundary relationships in Theorem 5.

In order to further verify the model constructed in this paper, we can observe the trend of changes in the benefit of the automobile manufacturing industry as the application cost of new-generation information technology changes while other parameters remain unchanged. The specific changes are shown in Figure 1. When the application cost of new-generation information technology is less than  $C_{IT}^T$ , the integration of new-generation information technology and the automobile manufacturing industry will increase economic benefits and positive changes in benefit. When the technology application cost is greater than the boundary value  $C_{IT}^T$ , the high cost of technology application undertaken by the automobile manufacturing industry will result

in a decline in benefit. At this time, the benefit change is negative, and the automobile manufacturing industry will abandon the application of new-generation information technology.

## 6. Conclusion

By building a cost-benefit model before and after the integration of new-generation information technology and the automobile industry, this article focuses on the analysis of the impact of new-generation information technology on upstream and downstream enterprises in the automotive manufacturing industry chain and compares the changes in logistics costs, manufacturing costs, and benefits of the automobile manufacturing industry before and after the integration of new-generation information technology. This paper analyzes the changes in the benefit of the automobile manufacturing industry based on the upper limit of the application cost of new-generation information technology ( $C_{IT}^T$ ) and obtains the basis for the fusion development of new-generation information technology and automobile manufacturing:

- (1) When the application cost of new-generation information technology is less than the boundary value ( $C_{IT}^T$ ), the benefit of the entire industry chain of automobile manufacturing will be improved.
- (2) After applying new-generation information technology, the value added to the downstream automobile manufacturing enterprises in the automobile manufacturing industry chain is greater than the value added to the upstream automobile component manufacturing enterprises. When the technology application cost is less than  $C_{IT}^S$ , both parts prices and car prices will decrease. When technology application costs are met  $C_{IT} \in [C_{IT}^S, C_{IT}^R]$ , the price of auto parts will increase, but the selling price of automobiles will still decrease. Auto parts manufacturing enterprises transfer part of the technology application costs to auto manufacturing enterprises.
- (3) The lower the application cost of the new-generation information technology, the impact on the number of automobile production will be greater. When the technology application cost is less than  $C_{IT}^Q$ , automobile production is increasing. In the process of integration and development of new-generation information technology and the automobile manufacturing industry, it is necessary to reasonably control the cost of technology application and put more automobile products on the market to obtain greater benefits.

The integration and development of new-generation information technology and the automobile manufacturing industry will transform the automobile manufacturing industry chain into an intelligent environment, enabling interconnection and real-time interaction between upstream and downstream enterprises in the industry chain. Under the effect of digital end-to-end integration technology, the

automobile manufacturing industry realizes digital, networked, and intelligent production. People, machinery equipment, and resources collaborate efficiently in smart factories to promote the automobile manufacturing industry to complete the upgrade of smart manufacturing technology.

In future research, we will consider adding car pricing contracts and technology upgrade paths. The upstream and downstream enterprises of the automobile manufacturing industry chain and the consumers in the market form a three-level supply chain to analyze the changes in the main parameters of the fusion development of new-generation information technology and the automobile manufacturing industry and infer a more realistic decision basis.

## Data Availability

The data used to support the findings of this study are included within the article.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## Authors' Contributions

All authors have read and agreed to the published version of the manuscript.

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