

# Research on the Influence of Subsidies on E-commerce Supply Chain Decision under the Background of Blockchain

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**Abstract:** Based on blockchain technology, this paper takes e-commerce supply chain decision-making as the research topic, and comprehensively considers many factors such as different consumer types, consumer traceability information, preference subsidy, etc., and constructs a business supply chain game model, and uses Stackelberg game theory to solve the equilibrium solution of the model. Finally, the results are verified by numerical simulation. It is found that the use of blockchain technology can always make the profits of supply chain enterprises higher regardless of whether subsidies are made or not. With the increase of subsidies, the profits of supply chain enterprises will increase. For consumers, general consumers can always benefit from blockchain technology, loyal consumers need subsidies under certain conditions, but the same is true. The greater the subsidies, the more consumers will benefit from blockchain technology. In addition, we find that subsidies can effectively improve social welfare, but there is a certain threshold beyond which the improvement effect will be weakened.

**Keywords:** Blockchain; Different consumer types; Subsidies; Consumer surplus; Social welfare.

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## 1. Introduction

In recent years, the e-commerce supply chain has developed rapidly. Combining e-commerce with the supply chain has become a mainstream trend in the current supply chain. However, due to information asymmetry and transaction process data mostly stored in the backend, the e-commerce supply chain still faces the problem of opaque information, consumer Blockchain technology provides new technical support to solve problems such as low trust and difficulty in tracing product sources. It has the characteristics of non-tampering, traceability, openness, transparency and decentralization [1]. Its distributed ledger, Core technologies such as asymmetric encryption, consensus mechanisms, and smart contracts can effectively connect upstream and downstream enterprise information in the supply chain to ensure the authenticity and reliability of transaction information [2]. Currently, many large e-commerce companies have begun to use blockchain technology. For example, JD.com, Suning, Walmart, Alibaba, etc. use blockchain traceability technology to track the production, processing, circulation, retail and other aspects of products to ensure that consumers The high quality and fidelity of the products in hand enhances consumers' trust in e-commerce platforms, thereby gaining a greater market share. Blockchain technology has become an endogenous driving force for current e-commerce companies, but for small e-commerce companies For enterprises, the large costs brought by the application of blockchain technology have made them prohibitive, and they have gradually lost their competitiveness in the market. In order to accelerate the transformation of the supply chain and the application of new technologies, as well as to promote the development of small

businesses and well-structured operations, subsidies are often used to promote the application of emerging technologies such as blockchain technology by enterprises. Currently, China includes Shanghai, Guangzhou, Hangzhou, Changsha, Qingdao, Guiyang, Chengdu, Zhuhai, Suzhou, Fuzhou and other cities and regions have issued special preferential subsidies specifically for the blockchain industry. These subsidy policies can, to a certain extent, solve the early-stage business problems faced by blockchain companies such as unclear business and lack of Implementation scenarios and other issues will truly promote the impact of blockchain technology on society.

Closely related to this article is the research on the application of blockchain in supply chains and the impact of subsidies on supply chain operational decisions. Currently, due to the significant advantages that blockchain technology brings to the supply chain, more and more scholars are beginning to pay attention to the application of blockchain technology in the supply chain. Zhang Lingrong et al. [3] have combined blockchain with subsidy strategies and consumers. Considering low-carbon preferences, the impact of technology subsidies and output subsidies on supply chain decisions and profits before and after the application of blockchain technology was studied., Liu Liang and Wu et al.[4-5]studied the impact of blockchain technology on fresh food Regarding the impact of e-commerce supply chains, it was found that blockchain technology can effectively solve the problems of circulation timeliness, consumer trust, and false reporting of freshness in the fresh food e-commerce supply chain. Hu Sensen et al. [6] combined learning efficiency and traceability preference to study the impact of blockchain technology on the agricultural product supply chain. Zhang et al. [7] studied the role of blockchain

technology on the digital transformation of cold chain supply chains and found that blockchain The adoption of technology may cause manufacturers to increase wholesale prices, but it will not lead to retailers ordering quantity; instead, it will increase order quantity. Zhao Huida, Chen Yanting[8-9] and others considered blockchain technology into the shipping supply chain and discussed the investment conditions of blockchain technology in the shipping supply chain and its impact on shipping supply chain decision-making. Sun Zhongmiao [10] and others considered the time cost and identification effect of blockchain technology on verifying product authenticity, and studied the optimal product pricing problem in the supply chain based on blockchain technology. In addition, some scholars [11-12] have found that blockchain technology can effectively prevent and combat moral hazard and counterfeiting problems in the supply chain.

On the other hand, the research is the influence of subsidies on supply chain operation decision-making. Han Tongyin et al. [13] studied the impact of subsidies on dual-channel green supply chain and found that subsidies can make some supply chain profits and coordinate the impact of fairness concerns on product pricing and greenness. Wang Daoping [14] found that subsidies can effectively regulate the distribution of profits among supply chain entities by analyzing the impact of subsidies on the decision-making behavior of upstream and downstream enterprises in the supply chain Some scholars also compare the effects of different subsidy forms For example, Sun Di and others [15] added two forms of subsidies, namely, green producer subsidies and consumer subsidies, to

the green supply chain and found that no matter which kind of subsidies can effectively improve the profits of the supply chain.

What is related to this paper is that the research of Wu [5] and Sun Zhongmiao [10] is different from them. This paper not only sets blockchain technology as an endogenous variable that supply chain enterprises can control by themselves, but also distinguishes consumers in the market according to loyalty. At the same time, it introduces two types of subsidies to discuss the impact of subsidies on e-commerce supply chain operation decisions when blockchain costs are endogenous and there are different types of consumers in the market. It provides a new perspective and reasonable suggestions for e-commerce supply chain decisions and subsidies.

## 2. Problem Description and Hypothesis

In this supply chain system, suppliers are responsible for the production of products, e-commerce enterprises are responsible for the online sales of products, and TPL is responsible for the distribution service of products. This supply chain adopts online sales instead of storage, that is, consumers place purchase orders on the website of e-commerce enterprises, and e-commerce enterprises send orders to suppliers, and suppliers hand over products to TPLs and finally deliver them to consumers Its supply chain structure diagram is shown in Figure 1.

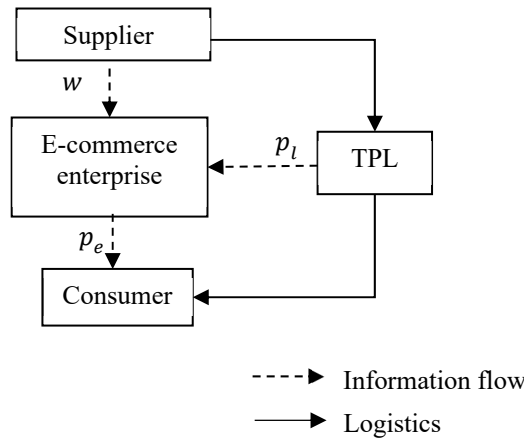


Figure 1. E-commerce supply chain structure diagram

In order to facilitate the modeling and solution of this paper, this paper needs to follow the following assumptions:

Hypothesis 1: Assuming the market demand is  $a$ , there are two kinds of consumers in the market: general consumers (indicated by subscript  $o$ ) are skeptical about the authenticity of the product, while loyal consumers (indicated by subscript  $f$ ) are not skeptical about the product The market share of loyal consumers is  $\mu$ , and the market share of general consumers is  $1 - \mu$ . The valuation of this product by two types of consumers is  $v$ , which obeys the uniform distribution on  $[0,1]$ , and its probability density function is  $f(\cdot)$ .

Hypothesis 2: Utility functions of general consumers and loyal consumers are  $U_{on} = v - p - \theta(1 - \delta)$ ,  $U_{fn} = v - p$  Only when  $v - p - \theta(1 - \delta) > 0$ ,  $v - p > 0$ , where  $v$  is the initial utility value of the product,  $0 < \delta < 1$  is the probability that general consumers think the product is

genuine  $(1 - \delta)$  is the probability that consumers think the product is fake, and  $\theta$  is the utility coefficient of fake products, which reflects the influence of fake products on consumers' utility.

Hypothesis 3: The traceability cost of blockchain technology is  $\frac{\phi e^2}{2}$ , where  $e$  is the traceability information level after the use of blockchain technology, and it is the cost coefficient of traceability using blockchain technology

Hypothesis 4: Giving certain innovation subsidies to the builders and investors of blockchain technology assumes that there are two forms of subsidies: the first is technological innovation subsidies, that is, the total cost of blockchain technology invested by e-commerce enterprises is subsidized according to a certain proportion, and the second form of subsidies is operating cost subsidies. The operating costs of the initiators and leaders of blockchain operation centers are

subsidized in proportion because considering that the operating costs related to blockchain technology are actually related to two factors. One is the market size, that is, the larger the market size, the greater the demand, the greater the total operating costs; The second is the level of blockchain traceability information. It is obvious that the higher the level of blockchain traceability information, the greater the energy and cost. Therefore, the operating cost subsidy is set as a function of the demand blockchain traceability information level.

In the parameter setting of this paper,  $\pi$  denotes the profit of the supply chain enterprise,  $w$  is the wholesale price,  $p_l$  is the logistics and distribution price,  $p_e$  is the product sales price, and  $c$  is the unit cost. In this paper, subscripts "  $s$  " "  $l$  " "  $e$  " denote suppliers, TPL and e-commerce enterprises, respectively, with subscripts "  $f$  " for loyal consumers and subscript "  $o$  " for average consumers, respectively, and subscript "  $N$  " "  $Bi$  " "  $Br$  " to denote the traditional e-commerce supply chain, the blockchain e-commerce supply chain subsidized by technological innovation, and the blockchain e-commerce supply chain subsidized by operation.

### 3. Model Establishment and Solution

#### 3.1. E-commerce supply chain model

Each subject of the supply chain makes decisions with the goal of maximizing its own interests. In the e-commerce supply chain structure, first, the supplier determines the wholesale price of products, then TPL determines the logistics service price after observing the wholesale price of products, and finally, the e-commerce enterprise determines the sales price of products. In the blockchain e-commerce supply chain, it is similar to Hu Sensen's research. First, the e-commerce enterprise determines the traceability level of blockchain, and other orders are consistent with the supply chain.

Construct the demand function of e-commerce supply chain according to the previous assumptions:

$$d_{oN} = (1 - \mu)a(1 - p_{eN} - \theta(1 - \delta)) \quad (1)$$

$$d_{fN} = \mu a(1 - p_{eN}) \quad (2)$$

$$d_N = d_{oN} + d_{fN} \quad (3)$$

The profit function of e-commerce supply chain is:

$$\pi_{sN} = D_N(w_N - c_s) \quad (4)$$

$$\pi_{lN} = D_N(p_{lN} - c_l) \quad (5)$$

$$\pi_{eN} = D_N(p_{eN} - w_N - p_{lN} - c_e) \quad (6)$$

In order to solve the problem conveniently, let  $A = \theta(1 - \delta)$ ,  $M = -1 + c_s + c_l + c_e$  use inductive method to solve the model. Firstly, solve the optimal selling price  $p_{eN}^*(w, p_{lN})$ , substitute it into equation (5), get  $p_{lN}^*(w)$ , then substitute it into equation (4),  $w^*$ , and finally inversely substitute  $w^*$  back to  $p_{lN}^*(w)$ 、 $p_{eN}^*(w, p_{lN})$ , the optimal decision value  $p_{eN}^*$ 、 $p_{lN}^*$  can be substituted into the demand and profit under equilibrium state in the profit and demand

function Supplier's optimal wholesale price  $w_N^* = \frac{-M+2c_s-A(1-u)}{2}$ , TPL's optimal logistics distribution price  $p_{lN}^* = \frac{-M+4c_l-A(1-u)}{4}$ , e-commerce enterprise's optimal sales price  $p_{eN}^* = \frac{8+M-7A(1-u)}{8}$ , The market demand are  $d_{oN}^* = \frac{(1-u)a(-M-A(1+7u))}{8}$ 、 $d_{fN}^* = \frac{ua(-M-7A(-1+u))}{8}$ 、 $d_N^* = \frac{a(-M-A(1-u))}{8}$ , supplier TPL e-commerce enterprises' profits are  $\pi_{sN}^* = \frac{a(M-A(-1+u))^2}{16}$ 、 $\pi_{lN}^* = \frac{a(M-A(-1+u))^2}{32}$ 、 $\pi_{eN}^* = \frac{a(M-A(-1+u))^2}{64}$ .

After solving the optimal decision demand and profit, refer to Sun Zhongmiao's solution to social welfare and consumer surplus from the perspective of social welfare, Under the decentralized decision of e-commerce supply chain, the general consumer loyalty and the consumer surplus social welfare of purchasing unit products are respectively  $CS_{oN}^* = \frac{(M+A(1+7u))^2}{128}$ 、 $CS_{fN}^* = \frac{(M-7A(1-u))^2}{128}$ 、 $SW_N^* = \frac{a(15M^2-30AM(-1+u)-A^2(-1+u)(15+49u))}{128}$ .

#### 3.2. Blockchain E-commerce Supply Chain under Technological Innovation Subsidy

Blockchain technology has the characteristics of traceability and non-tampering, which changes the acceptance of ordinary consumers to their products and eliminates the false negative utility of products. Combined with the previous assumption, the demand function after using blockchain technology are:

$$d_{oB} = (1 - \mu)a(1 - p_{eB} + \beta e) \quad (7)$$

$$d_{fB} = \mu a(1 - p_{eBi} + \beta e) \quad (8)$$

$$d_B = d_{oB} + d_{fB} \quad (9)$$

Providing technological innovation subsidies for e-commerce enterprises and sharing a certain proportion of technological costs for e-commerce enterprises. The profit functions under technological innovation subsidies and operating subsidies are divided into:

$$\pi_{sBi} = d_{Bi}(w_{Bi} - c_s) \quad (10)$$

$$\pi_{lBi} = d_{Bi}(p_{lBi} - c_l) \quad (11)$$

$$\pi_{eBi} = d_{Bi}(p_{eBi} - w_{Bi} - p_{lBi} - c_e) - (1 - \lambda_1) \frac{\phi e_i^2}{2} \quad (12)$$

In the same way, when the equilibrium condition  $\frac{a\beta^2}{32} + \phi(-1 + \lambda_1) < 0$ , the corresponding equilibrium solution is obtained as follows:

$$\begin{aligned}
w_{Bi}^* &= \frac{a\beta^2 c_s + 16(M+2-2c_l-2c_e)\phi(-1+\lambda_1)}{a\beta^2 + 32\phi(-1+\lambda_1)} \\
p_{lBi}^* &= \frac{a\beta^2 c_l - 8(M-4c_l)\phi(-1+\lambda_1)}{a\beta^2 + 32\phi(-1+\lambda_1)} \\
p_{eBi}^* &= \frac{a\beta^2(M+1) + 4(M+8)\phi(-1+\lambda_1)}{a\beta^2 + 32\phi(-1+\lambda_1)} \\
d_{oBi}^* &= \frac{4aM\phi(-1+\lambda_1)(-1+u)}{a\beta^2 + 32\phi(-1+\lambda_1)} \\
d_{fBi}^* &= -\frac{4aM\phi(-1+\lambda_1)u}{a\beta^2 + 32\phi(-1+\lambda_1)} \\
d_{Bi}^* &= -\frac{4aM\phi(-1+\lambda_1)}{a\beta^2 + 32\phi(-1+\lambda_1)} \\
\pi_{sBi}^* &= \frac{64aM^2\phi^2(-1+\lambda_1)^2}{(a\beta^2 + 32\phi(-1+\lambda_1))^2} \\
\pi_{lBi}^* &= \frac{32aM^2\phi^2(-1+\lambda_1)^2}{(a\beta^2 + 32\phi(-1+\lambda_1))^2} \\
\pi_{eBi}^* &= \frac{aM^2\phi(-1+\lambda_1)}{2a\beta^2 + 64\phi(-1+\lambda_1)} \\
CS_{oBi}^* &= CS_{fBi}^* = \frac{8M^2\phi^2(-1+\lambda_1)^2}{(a\beta^2 + 32\phi(-1+\lambda_1))^2} \\
SW_{Bi}^* &= \frac{aM^2\phi(-240\phi(-1+\lambda_1)^2 + a\beta^2(1+\lambda_1))}{2(a\beta^2 + 32\phi(-1+\lambda_1))^2}
\end{aligned}$$

### 3.3. Blockchain E-commerce Supply Chain under Operating Subsidy

Consistent with section 2.2, the demand function under operating subsidy is assumed as follows:

$$d_{oBr} = (1-\mu)a(1-p_{eBr} + \beta e_r) \quad (13)$$

$$d_{fBr} = \mu a(1-p_{eBr} + \beta e_r) \quad (14)$$

$$d_{Br} = d_{oBr} + d_{fBr} \quad (15)$$

The profit function of each subject in the supply chain is:

$$\pi_{sBr} = d_{Br}(w_{Br} - c_s) \quad (16)$$

$$\pi_{lBr} = d_{Br}(p_{lBr} - c_l) \quad (17)$$

$$\pi_{eBr} = d_{Br}(p_{eBr} - w_{Br} - p_{lBr} - c_e + \lambda_2 e_r) - \frac{\phi e_r^2}{2} \quad (18)$$

In the same way, when the equilibrium condition  $\frac{1}{32}(-32\phi + a(\beta + \lambda_2)^2) < 0$ , the corresponding equilibrium solution is obtained as follows:

$$\begin{aligned}
w_{Br}^* &= \frac{-16(M+2-2c_l-2c_e)\phi + a c_s(\beta + \lambda_2)^2}{-32\phi + a(\beta + \lambda_2)^2} \\
p_{lBr}^* &= \frac{8(M-4c_l)\phi + a c_l(\beta + \lambda_2)^2}{-32\phi + a(\beta + \lambda_2)^2} \\
p_{eBr}^* &= \frac{-4(8+M)\phi + a(\beta + \lambda_2)(\beta(M+1) + \lambda_2)}{-32\phi + a(\beta + \lambda_2)^2} \\
d_{oBr}^* &= -\frac{4aM\phi(-1+u)}{-32\phi + a(\beta + \lambda_2)^2} \\
d_{fBr}^* &= \frac{4aM\phi u}{-32\phi + a(\beta + \lambda_2)^2} \\
d_{Br}^* &= \frac{4aM\phi}{-32\phi + a(\beta + \lambda_2)^2} \\
\pi_{sBr}^* &= \frac{64aM^2\phi}{(-32\phi + a(\beta + \lambda_2)^2)^2} \\
\pi_{lBr}^* &= \frac{32aM^2\phi^2}{(-32\phi + a(\beta + \lambda_2)^2)^2}
\end{aligned}$$

$$\begin{aligned}
\pi_{eBr}^* &= -\frac{aM^2\phi}{2(-32\phi + a(\beta + \lambda_2)^2)} \\
CS_{oBr}^* &= CS_{fBr}^* = \frac{8M^2\phi^2}{(-32\phi + a(\beta + \lambda_2)^2)^2} \\
SW_{Br}^* &= -\frac{aM^2\phi(-240\phi + a(\beta^2 + 10\beta\lambda_2 + 9\lambda_2^2))}{2(-32\phi + a(\beta + \lambda_2)^2)^2}
\end{aligned}$$

## 4. Model Result Analyse

Proposition 1:  $e_i^*$ ,  $\pi_{sBi}^*$ ,  $\pi_{lBi}^*$ ,  $\pi_{eBi}^*$  is positively correlated with  $\lambda_1$ ,  $e_r^*$ ,  $\pi_{sBr}^*$ ,  $\pi_{lBr}^*$ ,  $\pi_{eBr}^*$  is positively correlated with  $\lambda_2$ .

$$\begin{aligned}
\text{Proof: } \frac{\partial e_i^*}{\partial \lambda_1} &= -\frac{32a\beta M\phi}{(a\beta^2 + 32\phi(-1+\lambda_1))^2} \\
\frac{\partial \pi_{sBi}^*}{\partial \lambda_1} &= \frac{128a^2\beta^2 M^2\phi^2(-1+\lambda_1)}{(a\beta^2 + 32\phi(-1+\lambda_1))^3} \\
\frac{\partial \pi_{lBi}^*}{\partial \lambda_1} &= \frac{64a^2\beta^2 M^2\phi^2(-1+\lambda_1)}{(a\beta^2 + 32\phi(-1+\lambda_1))^3} \\
\frac{\partial \pi_{eBi}^*}{\partial \lambda_1} &= \frac{a^2\beta^2 M^2\phi}{2(a\beta^2 + 32\phi(-1+\lambda_1))^2} \\
\frac{\partial e_r^*}{\partial \lambda_2} &= -\frac{aM(32\phi + a(\beta + \lambda_2)^2)}{(-32\phi + a(\beta + \lambda_2)^2)^2} \\
\frac{\partial \pi_{sBr}^*}{\partial \lambda_2} &= -\frac{256a^2 M^2\phi^2(\beta + \lambda_2)}{(-32\phi + a(\beta + \lambda_2)^2)^3} \\
\frac{\partial \pi_{lBr}^*}{\partial \lambda_2} &= -\frac{128a^2 M^2\phi^2(\beta + \lambda_2)}{(-32\phi + a(\beta + \lambda_2)^2)^3} \\
\frac{\partial \pi_{eBr}^*}{\partial \lambda_2} &= \frac{a^2 M^2\phi(\beta + \lambda_2)}{(-32\phi + a(\beta + \lambda_2)^2)^2}
\end{aligned}$$

Because the market demand is greater than 0,  $M < 0$  can be used, And because  $d_{Bi}^* > 0$ ,  $\lambda_1 < 1$ . The precondition of the solution is that  $\frac{a\beta^2}{32} + \phi(-1 + \lambda_1) < 0$ ,  $\frac{1}{32}(-32\phi + a(\beta + \lambda_2)^2) < 0$ , Easy to get  $\frac{\partial e_i^*}{\partial \lambda_1} > 0$ ,  $\frac{\partial \pi_{sBi}^*}{\partial \lambda_1} > 0$ ,  $\frac{\partial \pi_{lBi}^*}{\partial \lambda_1} > 0$ ,  $\frac{\partial \pi_{eBi}^*}{\partial \lambda_1} > 0$ ;  $\frac{\partial e_r^*}{\partial \lambda_2} > 0$ ,  $\frac{\partial \pi_{sBr}^*}{\partial \lambda_2} > 0$ ,  $\frac{\partial \pi_{lBr}^*}{\partial \lambda_2} > 0$ ,  $\frac{\partial \pi_{eBr}^*}{\partial \lambda_2} > 0$ .

Proposition 1 shows that both technological innovation subsidies and operating subsidies can effectively improve the blockchain traceability information level of e-commerce supply chain with the increase of subsidy coefficient. This is because technological innovation subsidies and operating subsidies are equivalent to the cost coefficient of blockchain technology. When the traceability cost of blockchain is reduced, enterprises will appropriately improve the level of blockchain to make greater profits. The increase of subsidies is beneficial to all main enterprises in the supply chain and will bring about an increase in profits. By means of subsidies, we can strengthen the application level of blockchain technology in e-commerce supply chain and accelerate the deepening of supply chain innovation and transformation.

Proposition 2:  $CS_{oBi}^*$ ,  $CS_{fBi}^*$  is positively correlated with  $\lambda_1$ ,  $CS_{oBr}^*$ ,  $CS_{fBr}^*$  is positively correlated with  $\lambda_2$ .

$$\begin{aligned}
\text{Proof: } \frac{\partial CS_{oBi}^*}{\partial \lambda_1} &= \frac{16a\beta^2 M^2\phi^2(-1+\lambda_1)}{(a\beta^2 + 32\phi(-1+\lambda_1))^3} \\
\frac{\partial CS_{fBi}^*}{\partial \lambda_1} &= \frac{16a\beta^2 M^2\phi^2(-1+\lambda_1)}{(a\beta^2 + 32\phi(-1+\lambda_1))^3} \\
\frac{\partial CS_{oBr}^*}{\partial \lambda_2} &= -\frac{32aM^2\phi^2(\beta + \lambda_2)}{(-32\phi + a(\beta + \lambda_2)^2)^3} \\
\frac{\partial CS_{fBr}^*}{\partial \lambda_2} &= -\frac{32aM^2\phi^2(\beta + \lambda_2)}{(-32\phi + a(\beta + \lambda_2)^2)^3}
\end{aligned}$$

As the above proof, it is known that when  $\lambda_1 < 1$ ,  $\frac{a\beta^2}{32} + \phi(-1 + \lambda_1) < 0$ ,  $M < 0$ ,  $\frac{1}{32}(-32\phi + a(\beta + \lambda_2)^2) < 0$  is easy to get  $(a\beta^2 + 32\phi(-1 + \lambda_1))^3 < 0$ ,  $16a\beta^2 M^2\phi^2(-1 + \lambda_1) < 0$ , therefore  $\frac{\partial CS_{oBi}^*}{\partial \lambda_1} > 0$ .

$$0, \frac{\partial CS_{fBi}^*}{\partial \lambda_1} > 0, \frac{\partial CS_{oBr}^*}{\partial \lambda_2} > 0, \frac{\partial CS_{fBr}^*}{\partial \lambda_2} > 0.$$

Proposition 2 shows that both technological innovation subsidies and operating subsidies are beneficial to both general consumers and loyal consumers with the increase of subsidy coefficient. Combination Proposition 1 shows that this benefit is caused by the improvement of traceability information level of blockchain, because both general consumers and loyal consumers have traceability information

$$\begin{aligned} \pi_{sBi}^* - \pi_{sN}^* &= -\frac{a(1024A\phi^2(-1+\lambda_1)^2(-2M+A(-1+u))(-1+u)+a^2\beta^4(M+A-Au)^2+64a\beta^2\phi(-1+\lambda_1)(M+A-Au)^2)}{16(a\beta^2+32\phi(-1+\lambda_1))^2} \\ \pi_{lBi}^* - \pi_{lN}^* &= -\frac{a(1024A\phi^2(-1+\lambda_1)^2(-2M+A(-1+u))(-1+u)+a^2\beta^4(M+A-Au)^2+64a\beta^2\phi(-1+\lambda_1)(M+A-Au)^2)}{32(a\beta^2+32\phi(-1+\lambda_1))^2} \\ \pi_{eBi}^* - \pi_{eN}^* &= -\frac{a(32A\phi(-1+\lambda_1)(-2M+A(-1+u))(-1+u)+a\beta^2(M+A-Au)^2)}{64(a\beta^2+32\phi(-1+\lambda_1))} \\ \pi_{sBr}^* - \pi_{sN}^* &= -\frac{a(1024A\phi^2(-2M+A(-1+u))(-1+u)-64a\phi(\beta+\lambda_2)^2(M+A-Au)^2+a^2(\beta+\lambda_2)^4(M+A-Au)^2)}{16(-32\phi+a(\beta+\lambda_2)^2)^2} \\ \pi_{lBr}^* - \pi_{lN}^* &= -\frac{a(1024A\phi^2(-2M+A(-1+u))(-1+u)-64a\phi(\beta+\lambda_2)^2(M+A-Au)^2+a^2(\beta+\lambda_2)^4(M+A-Au)^2)}{32(-32\phi+a(\beta+\lambda_2)^2)^2} \\ \pi_{eBr}^* - \pi_{eN}^* &= -\frac{a(-32A\phi(-2M+A(-1+u))(-1+u)+a(\beta+\lambda_2)^2(M+A-Au)^2)}{64(-32\phi+a(\beta+\lambda_2)^2)}. \end{aligned}$$

From the precondition of the existence of the solution, we can see that  $\frac{a\beta^2}{32} + \phi(-1 + \lambda_1) < 0$ ,  $-32\phi + a(\beta + \lambda_2)^2 < 0$ ,  $\lambda_1 < 1$ ,  $D_N^* = \frac{a(-M-A(1-u))}{8} > 0$  can be  $-M - A(1 - u) > 0$  and  $-M > 0$ . So  $\pi_{sBi}^* - \pi_{sN}^* > 0$ ,  $\pi_{lBi}^* - \pi_{lN}^* > 0$ ,  $\pi_{eBi}^* - \pi_{eN}^* > 0$ ;  $\pi_{sBr}^* - \pi_{sN}^* > 0$ ,  $\pi_{lBr}^* - \pi_{lN}^* > 0$ ,  $\pi_{eBr}^* - \pi_{eN}^* > 0$ .

Proposition 3 shows that the use of blockchain technology is beneficial to the profits of supply chain enterprises. The use of supply chain technology will increase the profits of supply chain enterprises. This is because enterprises can freely

$$\begin{aligned} \text{Proof: } CS_{oBi}^* - CS_{oN}^* &= -\frac{a^2\beta^4(M+A+7Au)^2+64a\beta^2\phi(-1+\lambda_1)(M+A+7Au)^2+1024A\phi^2(-1+\lambda_1)^2(1+7u)(A+2M+7Au)}{128(a\beta^2+32\phi(-1+\lambda_1))^2} \\ CS_{oBr}^* - CS_{oN}^* &= \\ &= -\frac{-64a\phi(\beta+\lambda_2)^2(M+A+7Au)^2+a^2(\beta+\lambda_2)^4(M+A+7Au)^2+1024A\phi^2(1+7u)(A+2M+7Au)}{128(-32\phi+a(\beta+\lambda_2)^2)^2} \end{aligned}$$

From the precondition of the existence of the solution, we can see that,  $\frac{a\beta^2}{32} + \phi(-1 + \lambda_1) < 0$ ,  $-32\phi + a(\beta + \lambda_2)^2 < 0$ ,  $\lambda_1 < 1$ ,  $D_N^* = \frac{a(-M-A(1-u))}{8} > 0$ , Easy get  $-M - A(1 + 7u) > 0$ ,  $-M > 0$ , So  $CS_{oBi}^* - CS_{oN}^* > 0$ ,  $CS_{oBr}^* - CS_{oN}^* > 0$ .

Proposition 4 shows that the use of blockchain technology is also beneficial to ordinary consumers. Before calculation, we can know that the use of blockchain technology eliminates ordinary consumers' doubts about products in terms of consumer utility, that is, eliminates the negative utility of products of ordinary consumers, which makes ordinary consumers feel more happy and happy. The improvement of ordinary consumers' surplus has nothing to do with subsidy coefficient, that is, ordinary consumers can always benefit from the use of blockchain technology when the premise solution exists.

## 5. Numerical Simulation

In order to make the research conclusions more reference and guiding value, this section uses numerical simulation method to more intuitively explore the impact of two blockchain subsidies on the profits of supply chain enterprises,

preference. When traceability information increases, the happiness and sense of purchasing products of two types of consumers will increase, and the increase of subsidies will benefit consumers in the whole market.

Proposition 3:  $\pi_{sBi}^* > \pi_{sN}^*$ ,  $\pi_{lBi}^* > \pi_{lN}^*$ ,  $\pi_{eBi}^* > \pi_{eN}^*$ ,  $\pi_{sBr}^* > \pi_{sN}^*$ ,  $\pi_{lBr}^* > \pi_{lN}^*$ ,  $\pi_{eBr}^* > \pi_{eN}^*$ .

Proof:

control their own blockchain technology level and make their own profits more reasonably. This increase in profits has nothing to do with the degree of subsidies, that is, when the precondition of the optimal solution is that the profits of each node enterprise in the blockchain e-commerce supply chain are always greater than the profits of e-commerce supply chain. Even if there is no subsidy, e-commerce supply chain should invest in blockchain technology to achieve greater economic benefits and market competitiveness.

Proposition 4:  $CS_{oBi}^* > CS_{oN}^*$ ,  $CS_{oBr}^* > CS_{oN}^*$ .

different types of consumers, consumer surplus and social welfare Referring to the research basic parameters of Wu and sun Zhongmiao and Hu Sensen et al. [5-6,10], the values are as follows:  $a = 10$ ,  $\beta = 0.3$ ,  $\phi = 0.6$ ,  $c_s = 0.05$ ,  $c_l = 0.02$ ,  $c_e = 0.01$ ,  $\delta = 0.8$ ,  $\theta = 0.5$ ,  $\delta = 0.8$ ,  $\theta = 0.5$ .

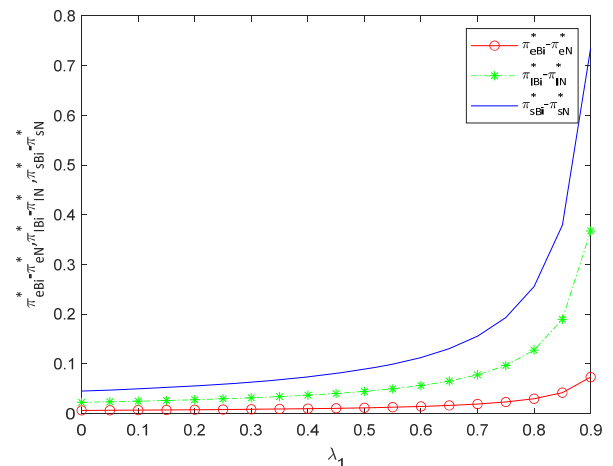
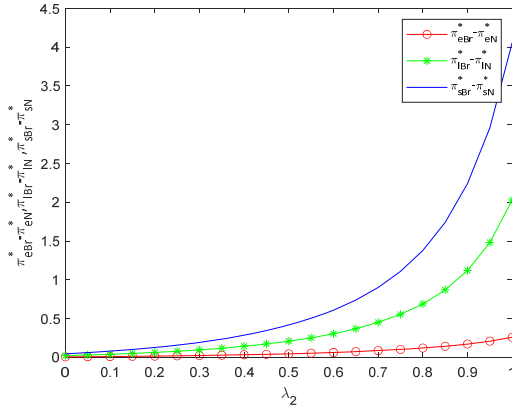
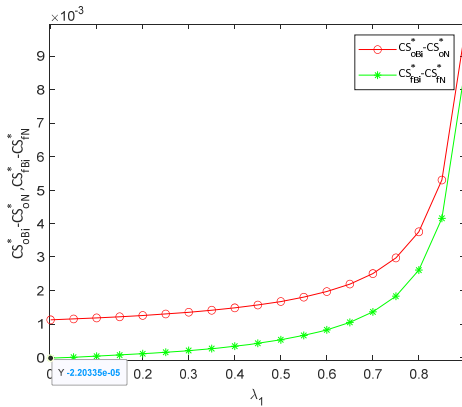


Figure 2. Influence of  $\lambda_1$  on profit difference of supply chain enterprises

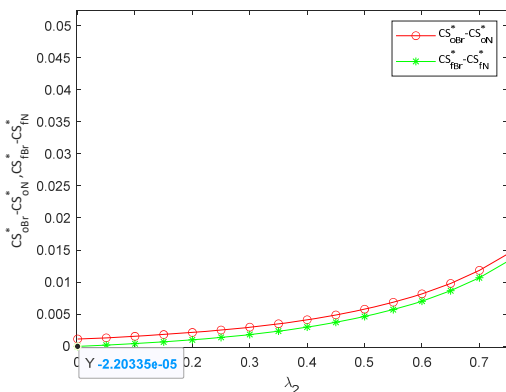


**Figure 3.** Influence of  $\lambda_2$  on profit difference of supply chain enterprises

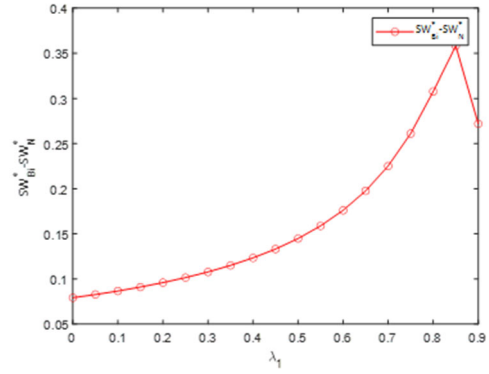
Figure 2 and Figure 3 reflect the influence of technical subsidy coefficient  $\lambda_1$  and operating subsidy coefficient  $\lambda_2$  on the profit difference of each main enterprise in the supply chain before and after the use of blockchain technology. From the figure, it can be seen that with the increase of subsidy coefficient, the greater the profit difference, that is, the increase of subsidy intensity, can make enterprises benefit more from the use of blockchain technology. From another point of view, even if there is no subsidy, using blockchain technology can also make each main enterprise have higher profits than e-commerce supply chain, which is consistent with the conclusion of the previous proposition. Enterprises using blockchain technology can improve their own profits regardless of the intensity of subsidies. But the strength of subsidies will increase the income of enterprises.



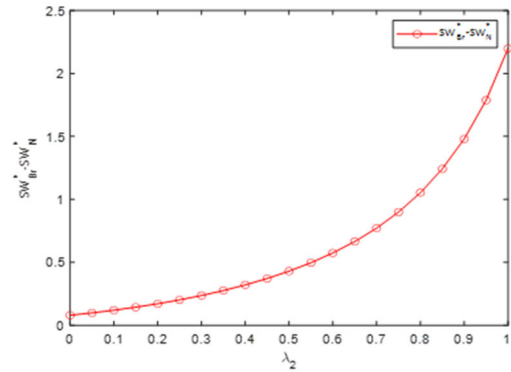
**Figure 4.** Influence of  $\lambda_1$  on the difference of consumer surplus



**Figure 5.** Influence of  $\lambda_2$  on the difference of consumer surplus



**Figure 6.** Influence of  $\lambda_1$  on social welfare difference



**Figure 7.** Influence of  $\lambda_2$  on social welfare difference

Figure 3-Figure 6 reflects the influence of different subsidy coefficients on the difference of different consumer residues in social welfare from the perspective of social welfare. From Figure 4-7., it can be seen that general consumers always benefit from the use of blockchain technology, that is, when the subsidy coefficient is 0, the general consumer residues in blockchain e-commerce supply chain are always greater than those in e-commerce supply chain. For loyal consumers' residues, whether technical subsidies or operating subsidies can always make loyal consumers benefit from the use of blockchain technology under certain threshold conditions. For social welfare, we find that subsidies can effectively improve social welfare, but there is a certain threshold. When this threshold is exceeded, social welfare will not increase with the increase of subsidy coefficient, but will decrease instead.

## 6. Conclusion and Prospect

This paper comprehensively considers many factors such as the existence of different types of consumers in the endogenous market of blockchain cost and consumers' preference for traceability information. This paper discusses the influence of subsidies on the operation decision of e-commerce supply chain. The main conclusions are as follows:

We find that both technical subsidies and operating subsidies can effectively improve the profits of each node enterprise in the e-commerce supply chain. When the subsidies are greater, the profits of e-commerce supply chain enterprises using blockchain technology will be greater. However, even if there is no subsidy, the profits of using blockchain technology will also be greater than that of e-commerce supply chain. Using blockchain technology is a wise strategy for e-commerce supply chain.

From the perspective of social welfare, both technical

subsidies and operating subsidies will increase with the increase of subsidies, that is, subsidies can benefit consumers in the market. For ordinary consumers, whether there is subsidies, he can always benefit from blockchain technology. For loyal consumers, subsidies can effectively improve social welfare when the subsidy coefficient has a certain threshold condition, but there is a certain threshold condition. When it exceeds this threshold condition, with the increase of subsidies, social welfare will decrease, that is, the improvement effect will become weak. However, in this study, it is assumed that only e-commerce enterprises bear the cost of blockchain use and do not further distribute profits. In the future, coordination contracts can be set from the perspective of profit distribution to make each enterprise in the supply chain more profitable.

## Acknowledgment

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