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Study of Government Subsidies and Manufacturers' Decision to Join the Blockchain

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Abstract: Based on the increase of people's environmental awareness and the application of blockchain technology in various fields, this paper combines blockchain and green supply chain, establishes a secondary supply chain led by manufacturers and followed by retailers, explores the pricing strategy and blockchain platform adoption conditions of the traditional green supply chain compared with the green supply chain that joins the blockchain platform, and considers the pricing strategy of government-subsidized manufacturers and blockchain platform adoption The paper also considers the pricing strategies and blockchain platform adoption conditions of government-subsidised manufacturers. Firstly, the paper finds that green supply chain companies do not join blockchain platforms in all cases. Manufacturers and retailers are motivated to join blockchain platforms when the cost of operating the platform is low and consumer trust in the value of the product is low. This is because the benefits of increased demand due to increased consumer trust in green products more than compensate for the cost of operating a blockchain platform. However, when companies join the blockchain platform, the retail price of green products will rise and consumers will not benefit from the blockchain platform. When the government subsidises manufacturers, manufacturers, retailers and consumers all benefit from the blockchain platform when green supply chain companies join the blockchain platform. Furthermore, demand for green products does not always increase when there are government subsidies.

Keywords: Blockchain, Consumer environmental awareness, Government subsidies.

1. Introduction

In response to the global climate problem, countries have made green emission reduction a production target, but at present, China's manufacturing industry's crude production methods still exist, and the energy consumption of the manufacturing industry and its products accounts for a high proportion of the country's energy consumption, which will require China's industry and manufacturing industry to carry out a thorough green and low-carbon transformation and development [1]. As the traditional supply chain changes, the platform will become the new carrier of the supply chain economy, and green becomes the new requirement of the supply chain economy. The green supply chain is an important path to achieve the goal of "carbon peaking and carbon neutrality" by practising the concept of green development.

The traditional supply chain model is the "push supply chain", i.e. "sell what is produced and consume what is sold". "Pull supply chain" means "sell what you consume, and consume what you sell". Modern supply chain development should be a "pull supply chain", as a platform supply chain, it is the innovative development of a "pull digital platform supply chain"[2]. At present, most of the platforms in China are designed with the platform market as the centre, the platform market designs the standard warehouse receipts, designs or launches the corresponding varieties, and all the trading parties trade around the "products" provided by the platform because the "products" of such trading are designed, often as a mere trading "bargaining chip", or a tool for speculation. Sometimes the information generated by the transaction is not the true supply and demand information of the market, misleading production and marketing. The current platform blockchain is designed in the same way, with the platform at the centre, rather than the "polycentric" design of the parties to the transaction[3]. With the growing share of the 2C platform economy, manufacturers will be rapidly influenced by the consumption habits and behaviours of demand consumers, and will even gradually start to transmit to the upstream enterprises in the manufacturing supply chain, which will bring huge changes to the economic model and technological development.

With the development of the times, people's awareness of the environment has gradually increased. Consumers' increased environmental awareness makes them more inclined to choose green products, such as electric cars and rechargeable batteries. A survey shows that about 20% of consumers are willing to buy green products, even if they cost more than non-green products[4]. Nowadays, many companies uphold the concept of sustainability and pay more attention to the production and distribution of green products. However, it is more common for green products to be more expensive to produce and less in demand than traditional products, especially when they are first introduced to the market and take a while to gain consumer acceptance[5]. For example, in the case of fluorine-free air conditioners, consumers unfamiliar with this new environmentally friendly product were given limited information about how these products compared to Prada's regular products[6], which may have made them hesitant to buy fluorine-free air conditioners, hence the low sales volume when they first entered the market, but as consumers became more aware, economies of scale have now been achieved in the production of fluorine-free refrigerators. At present, the barriers to consumers choosing to purchase efficient and environmentally friendly products and services are threefold: firstly, the high price of green products and the lack of trust; on the other hand, consumers currently obtain some information on the sustainability of green goods mainly through reference to green consumer groups or personal experience[7], and lack access to information on the sustainability of goods. At the same time, the majority of consumers are also suspicious of the multiple advertisements and promotions of green products and are unable to make purchasing decisions based on this information[8]. Amongst other things, information asymmetry has become the most important factor that prevents consumers from making purchasing decisions. Therefore, consumer trust in green products and the limited availability of green information may significantly impact the sale of green products.

First proposed by Satoshi Nakamoto[9], the blockchain uses cryptographic algorithms and consensus mechanisms to achieve a decentralized design that provides point-to-point transactions on a decentralized basis. Blockchain can effectively improve supply chain transparency, reduce transaction costs, build trust and promote supply chain sustainability[10]-[11]. In the blockchain technology environment, the competing strategies and outcomes among supply chain enterprises will also change. Therefore, the study of competing games among supply chain enterprises with the introduction of blockchain has become a new research hotspot in the field of supply chain management. Zheng et al. (2019)[12]investigated the problem of order quantity decisions and risk decisions in the spacecraft supply chain from the perspective of blockchain-facilitated information sharing. Choi (2019)[13] examines the impact of a blockchain-enabled platform sales model on the profits, consumer surplus and social welfare of luxury goods supply chain members. And Choi (2019)[14] also examines the issue of blockchain improving data quality perspectives on fashion supply chain ordering decisions and finds that implementing blockchain can help improve social welfare, but can weaken the profitability of the apparel supply chain. Shen et al. (2020) [15]studied product selection decisions on online sales platforms that sell both used and new products based on the perspective of blockchain disclosure of product quality information. Li Jian et al. (2020) [16] designed a blockchain technology-driven "blockchain + collaborative emission reduction" information-sharing mechanism to improve the efficiency of collaborative emission reduction among upstream and downstream enterprises in the supply chain. Xi et al. (2020)[17] studied the pricing and channel selection issues in a dual-channel supply chain in a blockchain technology environment. Niu et al. (2021)[18] studied the impact of tax differences on MNCs' participation in cross-border e-commerce blockchain in the case of competition between MNCs' direct sales channels and cross-border e-commerce platforms and showed that the implementation of blockchain was able to increase MNCs' wholesale profits but reduce MNCs' retail profits and tax planning benefits. Based on an omnichannel context, Xu et al. (2021)[19] show that the implementation of blockchain by manufacturers can not only increase product greenness but also facilitate supply chain coordination. Guan et al. (2021)[20] studied the impact of blockchain technology on cross-border supply chain decisions under different cooperation contracts in the context of tariff hikes. By using blockchain technology, we can guarantee accurate and real-time access to information. In which those involved can access the status, quantity and location of spare parts. Consumers can scan QR codes on their smartphones to obtain information about the product, which will reduce or eliminate their distrust of the product[21]-[22]. However, not all companies will use blockchain due to the additional operational costs involved in joining a blockchain platform. At this point, the first question arises: under what conditions will manufacturers and retailers join a blockchain platform when consumers do not trust green products?

To reduce costs and stimulate demand, the government can offer subsidies to manufacturers and retailers and tax breaks to purchasers[23]. For example, during the epidemic, the Italian government offered consumers a 'green' subsidy of up to 60% of the price of a bicycle, up to a maximum of €500 per inhabitant of a city with a population of 50,000 or more. In the green product supply chain, the different forms of government subsidies offered can influence the pricing strategies and product demand of firms in the supply chain[24]-[25]. A second question arises at this point: how do government subsidies affect the conditions under which companies choose to join a blockchain platform?

To address these two issues, this paper develops a model that first examines wholesale prices, retail prices, product demand and firm profits for traditional green supply chains and green supply chains that join a blockchain platform, and then analytically explores the conditions for firms to join a blockchain platform when the government provides subsidies to manufacturers, retailers and consumers, respectively[26]. Although blockchain can alleviate consumers' information uncertainty about green products, it requires firms to pay certain operational costs, so we consider three forms of government subsidies to manufacturers, retailers and consumers respectively, and analyse the wholesale prices, retail prices, product demand and firm profits of traditional green supply chains and green supply chains joining blockchain platforms under these three subsidies, as well as the green The conditions for green supply chains to join the blockchain platform. Government subsidies play an important role in the operational strategy of green product supply chains, so it is important to understand how the application of blockchain affects the process and how the blockchain itself is affected.

2. Model Construction and Analysis

In this section, we first examine the equilibrium decisions of manufacturers and retailers in a traditional supply chain and then analyse the equilibrium decisions of manufacturers and retailers joining the supply chain under a blockchain platform. This is a secondary supply chain where the manufacturer leads and the retailer follows[27]. Next, we explore the conditions under which manufacturers and retailers join the blockchain platform in pursuit of different value objectives and discuss the impact of blockchain on consumers[28]. The following are the assumptions of this thesis:

Assumption 1: A superscript of B represents a manufacturer making a retrofit to use blockchain technology, respectively, and a superscript of N represents a manufacturer not accepting blockchain technology.

Assumption 2: Consumers are sensitive to green products and insensitive to price. The demand function is sought through the utility function of the product. u is the basic value of the product, u is uniformly distributed in [0,1] with density $f(u) = 1$. β is the sensitivity of consumers to green products, $0 < \beta < 1$. λ is the trust of consumers in green products, $0 < \lambda < 1$; p is the selling price of green products; e is the greenness of the product ($e > 0$). Then, in the traditional case, the utility function of the green product is $U = u + \lambda\beta e - p$, where the manufacturer's trust $\lambda = 1$ if the manufacturer accepts the retrofit to use blockchain technology.

Assumption 3: Manufacturers who accept blockchain technology transformation will need to pay unit transformation cost b. Meanwhile, if manufacturers use blockchain technology, through the technology's ledger-based records, consumers can learn about the enterprise's products and transactions, etc. Enterprises will gain value v, such as ga ood reputation of the enterprise, more transaction opportunities and order volume, etc., if each transaction is very good. Since it is difficult to compare the size of the cost and gain value of the blockchain technology transformation, let $b-v$ be the manufacturer's platform cost when $b>v$, and let $v-b$ be the manufacturer's platform gain when $b<v$.

Assumption 4: A manufacturer producing a green product requires a green abatement input to the product that costs an abatement cost of $C_m=\frac{1}{2}\omega e^2$Omega is is the manufacturer's green abatement input factor. For the sake of generality, the manufacturer's other costs are assumed to be zero.

Assumption 5: The decision variables in this paper are the selling price p of the green product and the greenness e of the product ($e>0$).

Assumption 6: When the government gives subsidies to manufacturers, retailers and consumers, the total amount of subsidies is certain and is T. When the government gives subsidies to consumers, it gives a subsidy of s per unit to consumers who buy green products, then $s=\frac{T}{D}$.

Assumption 7: Social welfare consists of firm profit plus consumer surplus minus government expenditure. Consumer Surplus (CS), which is the difference between the consumer's willingness to pay (psychological maximum price) and the actual price paid, measures the additional benefit that the consumer perceives himself to have gained. For this paper, consumer surplus is the consumer's surplus of a product.

2.1. Green supply chain decision-making without a blockchain platform

In a traditional supply chain, the utility function for purchasing a green product is

$$U_1=u+\lambda\beta e-p \tag{1}$$

The total consumer valuation of a product consists of a basic valuation (u) and an environmental valuation (βe). As the greenness of products increases, their environmental value also increases. Due to information asymmetry between companies and consumers, consumers are unable to accurately and fully grasp the true attributes of green products and the actual green effort behaviour of companies, resulting in consumers not being able to fully trust the greenness of products, which exposes consumers to uncertainty about the value of green products, where $0<\lambda<1$, especially for innovative or fashionable products. In previous research [1], when blockchain is not introduced, we use the equation to represent the degree of consumer uncertainty in equation (1).

When $U_1\geq 0$, i.e. $u\geq p-\lambda\beta e$, the consumer will buy the product, so the demand $D_1=P\{U_1\geq 0\}=\int_{p-\lambda\beta e}^{1}f(u)du$. Since u is uniformly distributed in [0,1], its density $f(u)=1$.

Therefore, we can obtain the following demand function:

$$D_1=1+\lambda\beta e-p \tag{2}$$

Manufacturer's profit function:

$$\pi_m^N=w(1+\lambda\beta e-p)-\frac{1}{2}\omega e^2 \tag{3}$$

Retailers' profit function:

$$\pi_r^N=(p-w)(1+\lambda\beta e-p) \tag{4}$$

Theorem 1. Equilibrium decisions and profits of manufacturers and retailers in a traditional supply chain when $\omega>\frac{\lambda^2\beta^2}{4}$:

$$p^{N*}=\frac{3\omega}{4\omega-\lambda^2\beta^2}$$
$$w^{N*}=\frac{2\omega}{4\omega-\lambda^2\beta^2}$$
$$e^{N*}=\frac{\beta\lambda}{4\omega-\lambda^2\beta^2}$$
$$D^{N*}=\frac{\omega}{4\omega-\lambda^2\beta^2}$$
$$\pi_m^{N*}=\frac{\omega}{2(4\omega-\lambda^2\beta^2)}$$
$$\pi_r^{N*}=\frac{\omega^2}{(4\omega-\lambda^2\beta^2)^2}$$

Proposition 1. Impact of consumer sensitivity to green products β and consumer trust in green products λ on the equilibrium outcome in the case of not joining the blockchain platform:

$$\frac{\partial\pi_m^{N*}}{\partial\beta}>0,\frac{\partial\pi_r^{N*}}{\partial\beta}>0,\frac{\partial D^{N*}}{\partial\beta}>0,\frac{\partial e^{N*}}{\partial\beta}>0,\frac{\partial w^{N*}}{\partial\beta}>0,\frac{\partial p^{N*}}{\partial\beta}>0$$

$$\frac{\partial\pi_m^{N*}}{\partial\lambda}>0,\frac{\partial\pi_r^{N*}}{\partial\lambda}>0,\frac{\partial D^{N*}}{\partial\lambda}>0,\frac{\partial e^{N*}}{\partial\lambda}>0,\frac{\partial w^{N*}}{\partial\lambda}>0,\frac{\partial p^{N*}}{\partial\lambda}>0$$

Proposition 1 suggests that consumer sensitivity and trust in green products positively affect the selling price, wholesale price and greenness of products under different channels. Consumers' distrust of green products will reduce their desire to buy green products, which in turn will reduce the market demand for green products, which in turn will encourage manufacturers to reduce their green inputs into their products, resulting in a decrease in the greenness of their products, resulting in lower market demand for green products and a reduction in the profitability of each player, which will lead to a vicious circle in which each player in the green supply chain will have to choose lower wholesale and sales prices. This creates a vicious circle. To increase green consumption, both the government and enterprises should aim to enhance consumers' trust in green products. Enterprises should join the blockchain platform to build a decentralised green product information traceability system, so that consumers can trace the green information of products, and the green information can be guaranteed to be valid, which will maximise consumers' trust in green products.

2.2. Green supply chain decision-making by joining a blockchain platform

When companies join the blockchain platform, the transparency of information in the supply chain is optimised to the maximum extent and consumers can obtain not only green information by scanning QR codes, but also other basic information (related to traceability, logistics and quality of the product). The full lifecycle information of green products, especially greenness information, can be completely and accurately recorded and stored in the blockchain-supported product information traceability system, and consumers can fully trust the greenness of the products. Green information symmetry increases consumer trust in greenness, i.e. $\lambda = 1$.

At this point, the consumer surplus function for the green product purchased is

$$U_2 = u + \beta e - p \quad (5)$$

With that, we can obtain the demand function:

$$D_2 = 1 + \beta e - p \quad (6)$$

The profit function for manufacturers:

$$\pi_m^{BM} = (w - b + v)(1 + \beta e - p) - \frac{1}{2}\omega e^2 \quad (7)$$

The profit function for retailers:

$$\pi_r^{BM} = (p - w)(1 + \beta e - p) \quad (8)$$

Theorem 2. Equilibrium decisions and profits of manufacturers and retailers in a green supply chain joining a blockchain platform when $\omega > \frac{\beta^2}{4}$:

$$p^{B*} = \frac{\beta^2(v-b) + \omega(3+b-v)}{4\omega - \beta^2}$$

$$w^{B*} = \frac{\beta^2(v-b) + 2\omega(1+b-v)}{4\omega - \beta^2}$$

$$e^{B*} = \frac{\beta(1-b+v)}{4\omega - \beta^2}$$

$$D^{B*} = \frac{(1+v-b)\omega}{4\omega - \beta^2}$$

$$\pi_m^{B*} = \frac{(1+v-b)^2\omega}{2(4\omega - \beta^2)}$$

$$\pi_r^{B*} = \frac{(1+v-b)^2\omega^2}{(4\omega - \beta^2)^2}$$

Proposition 2. Impact of the value gain v gained by firms joining the blockchain platform on the equilibrium outcome in the implementation of the blockchain scenario:

$$\frac{\partial w^{B*}}{\partial v} > 0, \frac{\partial e^{B*}}{\partial v} > 0, \frac{\partial D^{B*}}{\partial v} > 0, \frac{\partial \pi_m^{B*}}{\partial v} > 0, \frac{\partial \pi_r^{B*}}{\partial v} > 0,$$

$$\frac{\partial p^{B*}}{\partial v}\begin{cases} > 0, \frac{\beta^2}{4} < \omega < \beta^2 \\ = 0, \quad \omega = \beta^2 \\ < 0, \frac{\beta^2}{4} < \omega < 1 \end{cases}$$

Proposition 2 suggests that the value gain gained by a firm joining a blockchain platform has a positive impact on wholesale prices, product greenness, demand, and optimal profits for each of the green supply chain actors. For green product manufacturers, the higher the value gain gained by firms joining the blockchain platform, the higher the manufacturer's pricing power over the product and the easier it are for the manufacturer to set higher wholesale prices. However, the retailer's selling price does not necessarily increase with the cost of operating the blockchain platform but depends on the relationship between the green input factor and consumer green sensitivity. When $\frac{\beta^2}{4} < \omega < \beta^2$, the retailer's selling price increases as the manufacturer's gain value increases; when $\omega = \beta^2$, the unit value gain does not affect the selling price of green products; when ω>β^2, the retailer's selling price decreases as the manufacturer's gain value increases. This means that in the case of $\omega > \beta^2$, the greater the value gain of the manufacturer from the blockchain platform, not only is it beneficial to increase the profit of the green supply chain, but it will also increase consumer demand as consumers can purchase green products at a lower price.

2.3. Conditions for manufacturers to join the blockchain platform

Green product manufacturers can increase consumer trust by joining a blockchain platform, but at the same time incur additional blockchain operational costs. Whether manufacturers are inclined to join a blockchain platform depends on the greenness of the product and the profitability of the green supply chain companies. Comparing the greenness of products before and after joining the blockchain platform, and the profitability of the manufacturer and retailer, a sufficient condition for manufacturers to join the blockchain is derived.

Proposition 3.

(1) $v - b > 0$;

(2) $0 < b - v < 1 - \sqrt{\frac{4\omega - \beta^2}{4\omega - \lambda^2\beta^2}}$.

Manufacturers will be willing to join the blockchain platform when the greenness of their products and the profitability of manufacturers and retailers are higher when companies in the green supply chain join the blockchain platform than when they do not.

Proposition 3 suggests that a sufficient condition for a manufacturer to join a blockchain platform is related to the relationship between the manufacturer's value gain and the operating costs of the blockchain platform. When the manufacturer's benefit from the platform is large enough to cover the platform operating costs and green inputs delivered by the manufacturer, then the manufacturer will not only be more profitable but will also have more incentive to improve the greenness of their products. At this point, the manufacturer can obtain smaller pricing and give the retailer a lower wholesale price, at which point the retailer's profits will also increase. However, when the value of the manufacturer's gain is less than the operational costs delivered, then only the manufacturer spends less on the platform and the manufacturer still has the incentive to implement blockchain. This provides a source of motivation and a realistic basis for the green supply chain to join the blockchain platform.

2.4. Social welfare

We use social welfare to measure whether manufacturers can benefit from joining the blockchain platform, using SW to represent social welfare, superscript N for manufacturers not joining the blockchain platform, and superscript B for manufacturers joining the blockchain platform, where the social welfare function = company profit + consumer surplus - government spending.

That is, $SW = \pi_m^* + \pi_r^* + \int_{p^*}^{1-\beta e^*}(1 - \alpha + \beta e^* - v)dv$, which can be found out the social welfare when the manufacturer does not join the blockchain platform and when it joins the blockchain platform, respectively.

Social benefits when manufacturers do not join the blockchain platform:

$$SW^N = \frac{\omega}{2(4\omega - \lambda\beta^2)} + \frac{\omega^2}{(4\omega - \lambda\beta^2)^2} + \frac{(1 + \lambda\beta e^{N*} - p^{N*})^2}{2} = \frac{\omega}{2(4\omega - \lambda^2\beta^2)} + \frac{\omega^2}{(4\omega - \lambda^2\beta^2)^2} + \frac{\omega^2}{2(4\omega - \lambda^2\beta^2)^2} = \frac{(7\omega - \lambda^2\beta^2)\omega}{2(4\omega - \lambda^2\beta^2)^2}$$

Social benefits for manufacturers when joining a blockchain platform:

$$SW^B = \frac{(1 + v - b)^2\omega}{2(4\omega - \beta^2)} + \frac{(1 + v - b)^2\omega^2}{(4\omega - \beta^2)^2} + \frac{(1 + \beta e^{B*} - p^{B*})^2}{2} = \frac{(1 + v - b)^2\omega}{2(4\omega - \beta^2)} + \frac{(1 + v - b)^2\omega^2}{(4\omega - \beta^2)^2} + \frac{\left((1 - b + v)\omega\right)^2}{2(\beta^2 - 4\omega)^2} = \frac{(1 - b + v)^2\omega(7\omega - \beta^2)}{2(\beta^2 - 4\omega)^2}$$

As there are two conditions for manufacturers to join the blockchain when pursuing environmental goals versus economic goals, we discuss below whether the social welfare of manufacturers will increase when they join the blockchain platform by the situation.

(1) When $v - b > 0$,

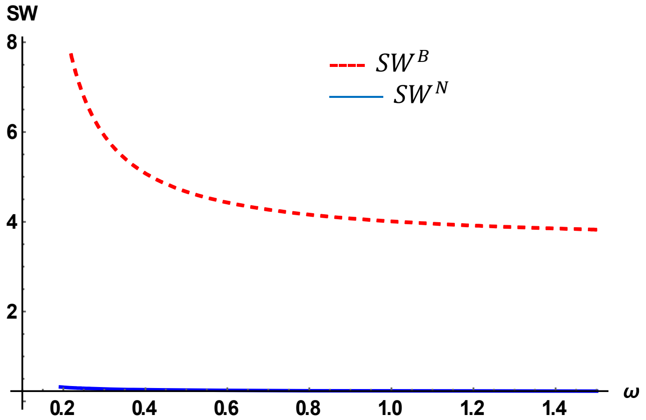

Figure 1. Image of social welfare on green input coefficient

The manufacturer's value gain from the platform is higher than the cost of operating the platform so that $v = 5$, $b = 2$, $\beta = 0.6$ and $\lambda = 0.7$, and the image is made about SW^N and SW^B concerning the green input coefficient ω. To ensure positive prices, profits and product greenness for manufacturers and retailers, $\omega > \frac{\beta^2}{4}$ is specified, and the green input coefficient ω for manufacturers in the image starts at 0.1. As can be seen from the image, as the green input factor ω increases, the cost to the manufacturer increases and social welfare decreases. However, the social welfare of manufacturers joining the blockchain platform is much higher than those not joining the blockchain platform. In this case, $SW^B > SW^N$.

(2) When $0 < b - v < 1 - \sqrt{\frac{4\omega - \beta^2}{4\omega - \lambda^2\beta^2}}$,

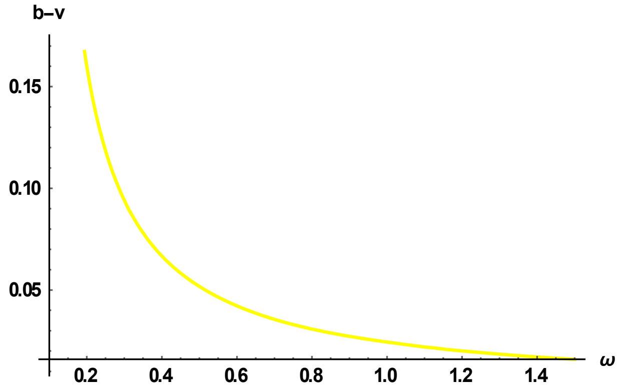

Figure 2. Image of the platform fee on the green input factor

The formula shows that the manufacturer's platform spend is related to the green input coefficient, so that $\beta = 0.6$ and $\lambda = 0.7$, making an image about $b - v$ concerning the green input coefficient ω. As the manufacturer's green input coefficient increases, the manufacturer's platform spending decreases, increasing the conditions for the manufacturer to join the blockchain platform. The following selections of $b - v = 0.05$, $b - v = 0.1$ and $b - v = 0.15$ are used to compare the change in social welfare.

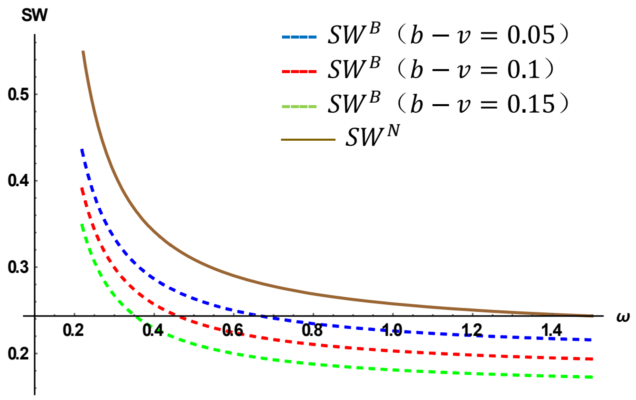

Figure 3. Image of social welfare on green input coefficient

The manufacturer's value gain from the platform is lower than the cost of operating the platform, so $b - v = 0.05$, $b - v = 0.1$ and $b - v = 0.15$, $\beta = 0.6$ and $\lambda = 0.7$, respectively, make images of SW^N and SW^B concerning the green input coefficient ω. To ensure positive prices, profits and product greenness for manufacturers and retailers, $\omega > \frac{\beta^2}{4}$ is specified, and the green input coefficient ω for manufacturers in the images starts from 0.1. As can be seen from the image, as the green input coefficient ω increases, the green input cost to the manufacturer increases, along with the cost of the platform, and social welfare decreases, while the social welfare of the manufacturer joining the blockchain platform decreases as the platform cost to the manufacturer increases. Overall, the social welfare of manufacturers joining the blockchain platform is lower than that without joining the blockchain platform, i.e. $SW^B < SW^N$.

Proposition 4. When a manufacturer joins a blockchain platform, $SW^B > SW^N$ if the manufacturer gains from the platform, and $SW^B < SW^N$ if the manufacturer pays for the platform.

Proposition 4 yields a change in social welfare in different cases after the green manufacturer joins the blockchain platform. Social welfare increases after a manufacturer joins the blockchain platform only if the manufacturer receives additional benefits. Meanwhile $D^B > D^N$ and $p^B < p^N$, the demand and greenness of the product will increase, but the selling price of the product is reversed. As the green input increases, the selling price will increase accordingly to balance the increase in cost.

To encourage manufacturers and retailers to join the blockchain platform, in addition to reducing the operating costs of the platform delivered by firms, the demand for green products should also be raised. In the next section, we explore how the conditions for manufacturers and retailers to join the blockchain are affected under different subsidy conditions, from a government incentive perspective, by providing subsidies to manufacturers, retailers and consumers respectively.

3. Government-subsidised Manufacturers

To encourage manufacturers to join blockchain platforms and monitor their production of green products, governments can provide appropriate subsidy incentives, choosing to subsidise economic activities related to green products. In this section, we further explore the impact of government subsidies on blockchain technology adoption, examining the case of government subsidies to manufacturers

In this section, we use the superscript " SM " to denote government subsidies to manufacturers, " N " for manufacturers not joining the blockchain platform, and " B " for manufacturers joining the blockchain platform. The government shares part of the green cost of the manufacturer, with a share of θ.

3.1. Green supply chain for manufacturers who do not join the blockchain platform

Manufacturer's profit function:

$$\pi_m^N = w(1+\lambda\beta e - p) - \frac{1}{2}\omega(1-\theta)e^2 \tag{11}$$

Retailers' profit function:

$$\pi_r^N = (p-w)(1+\lambda\beta e - p) \tag{12}$$

Theorem 3. Equilibrium decisions and profits of manufacturers and retailers in a supply chain joining a blockchain platform when $\omega > \frac{\lambda^2\beta^2}{4(1-\theta)}$:

$$p^{NSM*} = \frac{3(1-\theta)\omega}{4(1-\theta)\omega - \lambda^2\beta^2}$$
$$w^{NSM*} = \frac{2(1-\theta)\omega}{4(1-\theta)\omega - \lambda^2\beta^2}$$
$$e^{NSM*} = \frac{\lambda\beta}{4(1-\theta)\omega - \lambda^2\beta^2}$$
$$D^{NSM*} = \frac{(1-\theta)\omega}{4(1-\theta)\omega - \lambda^2\beta^2}$$
$$\pi_m^{NSM*} = \frac{(1-\theta)\omega}{2(4(1-\theta)\omega - \lambda^2\beta^2)}$$
$$\pi_r^{NSM*} = \frac{(1-\theta)^2\omega^2}{(4(1-\theta)\omega - \lambda^2\beta^2)^2}$$

3.2. Manufacturers join the green supply chain on blockchain platforms

The profit function of manufacturer:

$$\pi_m^B = (w-b+v)(1+\beta e - p) - \frac{1}{2}\omega e^2 + T \tag{13}$$

The profit function of retailer:

$$\pi_r^B = (p-w)(1+\beta e - p) \tag{14}$$

Theorem 4. Equilibrium decisions and profits of manufacturers and retailers in a supply chain joining the blockchain platform when $\omega > \frac{\beta^2}{4(1-\theta)}$:

$$p^{BSM*} = \frac{3(1-\theta)\omega + (v-b)(\beta^2 - (1-\theta)\omega)}{4(1-\theta)\omega - \beta^2}$$
$$w^{BSM*} = \frac{2\omega(1-\theta) + (v-b)(\beta^2 - 2\omega(1-\theta))}{4(1-\theta)\omega - \beta^2}$$
$$e^{BSM*} = \frac{(1-b+v)\beta}{4(1-\theta)\omega - \beta^2}$$
$$D^{BSM*} = \frac{(1-b+v)(1-\theta)\omega}{4(1-\theta)\omega - \beta^2}$$
$$\pi_m^{BSM*} = \frac{(1-b+v)^2(1-\theta)\omega}{2(4(1-\theta)\omega - \beta^2)}$$
$$\pi_r^{BSM*} = \frac{(1-b+v)^2(1-\theta)^2\omega^2}{(4(1-\theta)\omega - \beta^2)^2}$$

3.2.1. Conditions for manufacturers to join blockchain platforms under environmental and economic objectives

Proposition 5. The government subsidy factor for manufacturers $0 < \theta < \frac{4\omega - \beta^2}{4\omega}$ and the greenness of the product and the profit of the firm after the manufacturer joins the blockchain platform is greater than without joining the blockchain platform, under the following conditions:

(1) $v - b > 0$,

(2) $0 < b - v < 1 - \sqrt{\frac{4\omega(1-\theta)-\beta^2}{4\omega(1-\theta)-\beta^2\lambda^2}}$.

Under the above conditions, manufacturers will be willing to join the blockchain platform.

Proposition 5 gives sufficient conditions for manufacturers to choose to join the blockchain platform in pursuit of product greenness and increased corporate profits in the case of government subsidies to manufacturers. To ensure that the coefficients are eligible, the government subsidy is in a certain range, i.e. $0 < \theta < \frac{4\omega - \beta^2}{4\omega}$. Manufacturers are willing to join the blockchain platform when their gain value is higher than the platform operating cost; manufacturers are willing to join the blockchain platform when their gain value is lower than the platform operating cost and when their platform cost is below a certain threshold.

3.2.2. Social welfare

The social welfare function is

$\mathrm{SW} = \pi_m + \pi_r + \int_{p^*}^{1-\beta e^*}(1+\beta e^* - v)dv - T - G.$

When no government subsidies are given to manufacturers and manufacturers do not join the blockchain platform, the social welfare function is

$$SW^{NSM} = \frac{(1-\theta)\omega}{2(4(1-\theta)\omega-\lambda^2\beta^2)} + \frac{(1-\theta)^2\omega^2}{(4(1-\theta)\omega-\lambda^2\beta^2)^2} + \frac{(1-\alpha+\lambda\beta e^{NSM*}-p^{NSM*})^2}{2} - \frac{1}{2}\omega\theta e^{NSM*2} - G$$
$$= \frac{(1-\theta)\omega}{2(4(1-\theta)\omega-\lambda^2\beta^2)} + \frac{(1-\theta)^2\omega^2}{(4(1-\theta)\omega-\lambda^2\beta^2)^2} + \frac{(1-\theta)^2\omega^2}{2(4(1-\theta)\omega-\lambda^2\beta^2)^2} - \frac{\beta^2\theta\lambda^2\omega}{2(4(1-\theta)\omega-\lambda^2\beta^2)^2} - G$$
$$= \frac{\omega(7(1-\theta)^2\omega-\beta^2\lambda^2)}{2(4(1-\theta)\omega-\lambda^2\beta^2)^2} - G$$

When government subsidies are given to manufacturers and they join the blockchain platform, the social welfare function is

$$SW^{BSM} = \frac{(1-b+v)^2(1-\theta)\omega}{2(4(1-\theta)\omega-\beta^2)} + \frac{(1-b+v)^2(1-\theta)^2\omega^2}{(4(1-\theta)\omega-\beta^2)^2} + \frac{(1+\beta e^{BSM*}-p^{BSM*})^2}{2} - \frac{1}{2}\omega\theta e^{BSM*2} - G$$
$$= \frac{(1-b+v)^2(1-\theta)\omega}{2(4(1-\theta)\omega-\beta^2)} + \frac{(1-b+v)^2(1-\theta)^2\omega^2}{(4(1-\theta)\omega-\beta^2)^2} + \frac{(1-b+v)^2(-1+\theta)^2\omega^2}{2(\beta^2+4(-1+\theta)\omega)^2} - \frac{(1-b+v)^2\beta^2\theta\omega}{2(\beta^2+4(-1+\theta)\omega)^2} - G$$
$$= \frac{(1-b+v)^2\omega(7(1-\theta)^2\omega-\beta^2)}{2(4(1-\theta)\omega-\beta^2)^2} - G$$

The following discusses whether social welfare increases when manufacturers are willing to join blockchain platforms.

(1) When $v - b > 0$

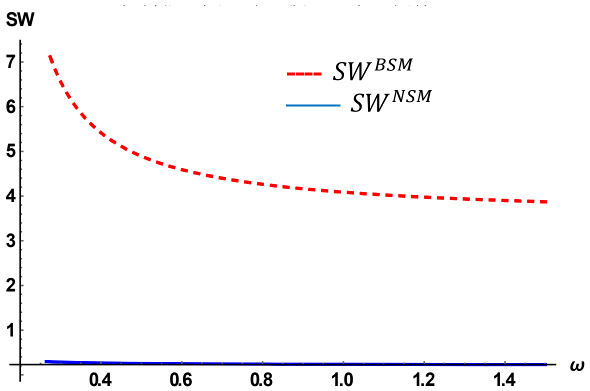

Figure 4. Image of social welfare on green input coefficient

The manufacturer's value gain from the platform is higher than the cost of operating the platform, so that $v = 5$, $b = 2$, $\beta = 0.6$, $\lambda = 0.7$ and $\theta = 0.2$, and the images of SW^{NSM} and SW^{BSM} are made concerning the green input coefficient ω. To ensure positive prices, profits and product greenness for manufacturers and retailers, $\omega > \frac{\beta^2}{4}$ is specified, and the green input coefficient ω for manufacturers in the image starts at 0.2. As can be seen from the image, as the green input factor ω increases, the cost to the manufacturer increases and social welfare decreases. However, the social welfare of manufacturers joining the blockchain platform is much higher than those not joining the blockchain platform. In this case, $SW^{BSM} > SW^{NSM}$.

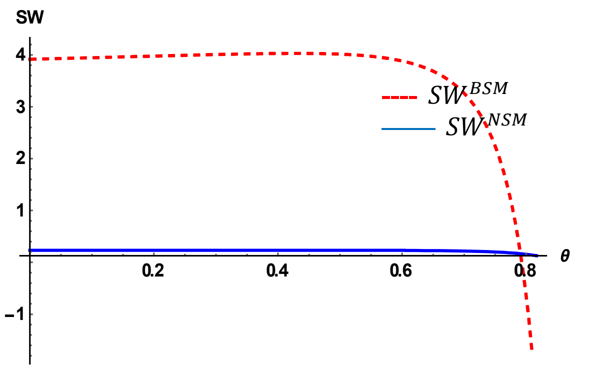

Figure 5. Images of social welfare regarding government subsidies

The value gain of the manufacturer from the platform is higher than the cost of operating the platform, so that $v = 5$, $b = 2$, $\beta = 0.6$, $\lambda = 0.7$ and $\omega = 1.2$, and an image of SW^{NSM} and SW^{BSM} concerning the green coefficient θ of the government subsidy to the manufacturer's input is made. To ensure that the variables are meaningful, the government subsidy coefficient for manufacturers is therefore $0 < \theta < \frac{4\omega-\beta^2}{4\omega}$, with θ ranging from 0 to 0.925 in the graph. Both social welfares decreases as the government subsidy increases, but the decline in social welfare is greater for manufacturers joining the blockchain platform, becoming negative at around $\theta = 0.8$. Although manufacturers gain from joining the blockchain platform, as the government's commitment to the manufacturer's green standards increases, the firm's profits are slowly insufficient to cover the government's expenses, and thus social welfare decreases or even becomes negative. However, overall, $SW^{BSM} > SW^{NSM}$. Only when the government's contribution to manufacturers' green inputs is large, $SW^{BSM} < SW^{NSM}$.

(3) When $0 < b - v < 1 - \sqrt{\frac{4\omega(1-\theta)-\beta^2}{4\omega(1-\theta)-\beta^2\lambda^2}}$

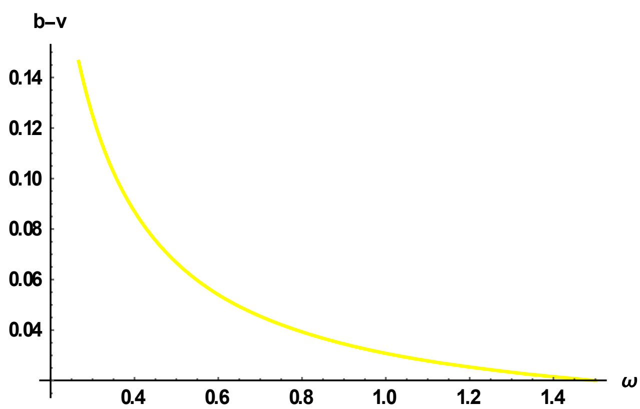

Figure 6. Image of platform costs on green input factor

The value gain gained by the manufacturer from the platform is lower than the cost of operating the platform, so that $\beta = 0.6$, $\lambda = 0.7$ and $\theta = 0.2$, and the image of the platform cost $b - v$ concerning the green input factor ω is made. It can be seen that as the manufacturer's green input factor increases, the platform spending slowly decreases.

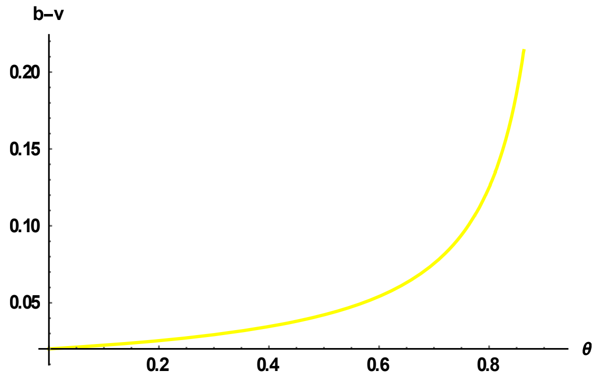

Figure 7. Image of platform costs on manufacturers' green input factors under government subsidies

The value gain of the manufacturer from the platform is lower than the cost of operating the platform, so that $\beta = 0.6$, $\lambda = 0.7$ and $\omega = 1.2$, and the image of the platform cost $b - v$ concerning the green factor θ of the government subsidised manufacturer input is made. It can be seen that as the government subsidy coefficient increases, the platform spending will gradually increase.

Combining Figure 6 and Figure 7, $b - v = 0.05$, $b - v = 0.1$ and $b - v = 0.14$ were selected when making the images of social welfare about the manufacturer's green input coefficient and government subsidy coefficient, respectively.

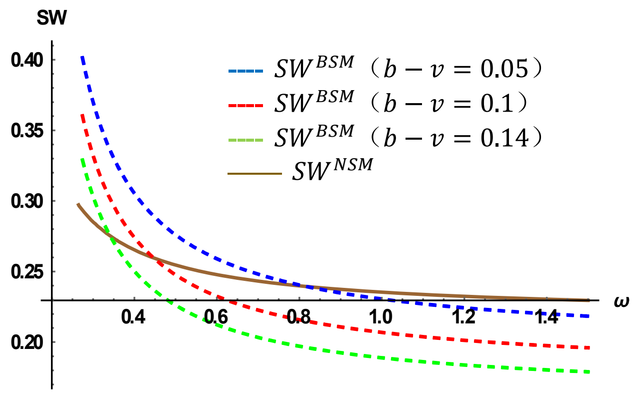

Figure 8. Image of social welfare on manufacturer's green input coefficient

The value gain of the manufacturer from the platform is lower than the cost of operating the platform, so that $b - v = 0.05$, $b - v = 0.1$ and $b - v = 0.14$, $\beta = 0.6$, $\lambda = 0.7$ and θ = 0.2, the images of SW^{NSM} and SW^{BSM} about the manufacturer's green input coefficient ω are made. From the images, we can see that as the green input coefficient of manufacturers increases, social welfare is on a downward trend. The cost that manufacturers need to bear is not only the cost of the platform but also the cost of green input. And social welfare is higher when the manufacturer joins the blockchain platform and the delivered platform spends less. When the manufacturer's green input coefficient is small, the social welfare of the manufacturer joining the blockchain platform is higher than the social welfare of the manufacturer not joining the platform, while as the green input coefficient increases, the social welfare of the manufacturer with higher platform costs delivered is first lower than the social welfare of the manufacturer not joining the platform. Therefore, while ensuring that the variables are meaningful, when the green input coefficient of manufacturers is very small, $SW^{BSM} > SW^{NSM}$,otherwise, $SW^{BSM} < SW^{NSM}$.

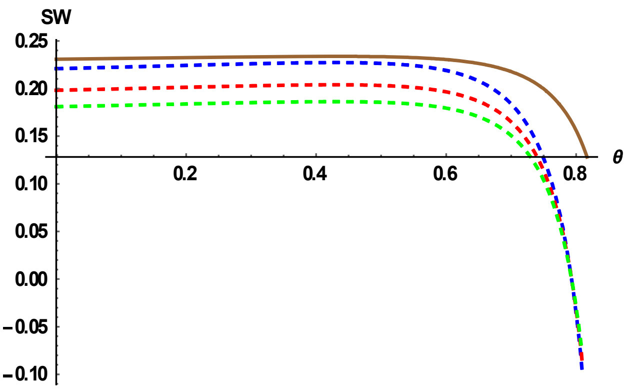

Figure 9. Images of social welfare regarding government subsidies

The value gain of the manufacturer from the platform is lower than the cost of operating the platform, and the images of SW^{NSM} and SW^{BSM} concerning the green coefficient θ of the government-subsidized manufacturer input are made when $b - v = 0.05$, $b - v = 0.1$ and $b - v = 0.14$, $\beta = 0.6$, $\lambda = 0.7$ and $\omega = 1.2$. From the images, it can be seen that both social welfares decrease as the government subsidy increases, but the social welfare of manufacturers joining the blockchain platform is lower than that of manufacturers not joining the blockchain platform. Even manufacturers who join the blockchain platform have to pay extra for the platform, so when the government bears the higher green cost of manufacturers, the net profit of the company is not enough to cover the government's expense, and the social welfare becomes negative at that time. Moreover, when manufacturers join the blockchain platform, they will pay more costs for platform expenses than if they do not join the platform, so $SW^{BSM} < SW^{NSM}$.

Proposition 6. When manufacturers join the blockchain platform, $SW^{BSM} > SW^{NSM}$ for $v - b > 0$. For $0 < b - v < 1 - \sqrt{\frac{4\omega(1-\theta)-\beta^2}{4\omega(1-\theta)-\beta^2\lambda^2}}$, $SW^{BSM} > SW^{NSM}$ when the manufacturer's green cost factor is variable and only when this factor is very small, otherwise $SW^{BSM} < SW^{NSM}$. When government subsidies are the variable, $SW^{BSM} < SW^{NSM}$.

Proposition 6 shows that under different conditions, social welfare is different. Social welfare rises when the government pays less than the net value added by manufacturers and retailers. Social welfare is higher when the manufacturer joins the platform and receives the benefits of the platform than if they do not join the blockchain platform, and when the government does not take on too much of the manufacturer's green input. When the manufacturer has to pay for the platform after joining the blockchain platform, it relies on the green input coefficient of the manufacturer at this time, and only when the green input coefficient is small, $SW^{BSM} > SW^{NSM}$. While when the green input coefficient of the manufacturer is large, if the manufacturer spends the platform cost, $SW^{BSM} < SW^{NSM}$ regardless of the government subsidy.

4. Conclusion

Based on the increasing environmental awareness and the application of blockchain technology in various fields, this paper combines blockchain and green supply chains, establishes a secondary supply chain led by manufacturers and followed by retailers, explores the pricing strategy and blockchain platform adoption conditions of the traditional green supply chain compared with the green supply chain that joins the blockchain platform, and considers the pricing strategy and blockchain platform adoption conditions of government subsidised manufacturers, retailers and consumers. We also consider the pricing strategies and blockchain platform adoption conditions of government-subsidised manufacturers, retailers and consumers.

Our key findings and insights are summarised below. We found that manufacturers are motivated to join blockchain platforms when manufacturers and retailers pursue the green value of their products with their economic value, when manufacturers can capture the benefits of the platform, or when manufacturers' platform spend is low. Because joining a blockchain platform can significantly increase consumer trust and the greenness of a product, thus increasing the market demand for green products, both manufacturers and retailers can gain more from the expanded market demand, which at this point can cover the operational costs associated with a blockchain platform. The manufacturer's cost investment affects the retailer's selling price. The manufacturer's acceptance of the blockchain platform will increase the manufacturer's costs and thus the selling price of the product, and the consumer does not benefit from the blockchain platform. However, the blockchain platform will enable consumers to have access to more complete information about the product, increasing consumer trust in the greenness of the product and thus increasing consumer demand. At the same time, consumer trust in the greenness of products can influence manufacturers to pursue environmental value goals. With these combined effects, manufacturers will embrace the blockchain platform and social welfare will increase. Governments are often concerned with the phenomenon of environmental protection and can therefore create subsidy incentives that increase demand for green products and induce manufacturers and retailers to join the blockchain platform, and they can encourage manufacturers to join the blockchain platform by giving subsidies.

Next, we further explore the impact of government subsidy schemes on the acceptance of blockchain platforms. In this paper, we find that when the government subsidises manufacturers, we find that the conditions for manufacturers to join the blockchain platform at this point are also related to the manufacturer's green input factor and the green product market erosion factor. When the manufacturer receives the platform benefits, the green factor if smaller also needs to ensure that the market weakening factor of green products is larger; the manufacturer's green factor is larger, when the market weakening factor of green products is smaller, and the manufacturer's platform benefits reach a certain threshold before they can. At this point the manufacturer's green input is small or the government subsidy is small, and the net value of corporate profits is higher than the government payout before social welfare increases. When the manufacturer pays a platform to spend, the platform spend needs to be below a certain threshold regardless of the manufacturer's green factor, but a larger green factor also needs to limit the green product market erosion factor to be larger. At this point only the manufacturer's green factor is small, and social welfare increases regardless of government subsidies. And we find that the demand for green products added to the platform always increases at this time, but the selling price of green products does not necessarily, the increase in demand is related to the green input factor of the manufacturer. However, whenever government subsidies are given, the conditions for manufacturers to join the blockchain platform are reduced. Therefore, there is an interactive effect between government subsidy policies and blockchain technology adoption. Governments often issue different types of subsidy policies to support the development of green products, and our findings suggest that companies should consider these subsidy policies when deciding whether to join a blockchain platform.

Our study still has some limitations; firstly, the manufacturer's gain value is static and does not consider the impact of dynamic gain value on the green supply chain. Secondly, in reality, there is often not a simple correspondence between one manufacturer and one retailer; multiple manufacturers and multiple retailers are also in direct competition, which is not considered in this paper. Thirdly, demand is not necessarily linear and stochastic demand is more realistic.

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