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Green Technology Investment with Data-Driven Marketing and Government Subsidy in a Platform Supply Chain

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Abstract: Expanding green consumption market and precise data promotion advantages make the platform economy have a significant effect on influencing manufacturers to carry out green R&D and production activities, and government subsidies have a positive incentive effect. In this context, for the studies about platform supply chain management with manufacturer's green production and the platform's marketing activities simultaneously are rare, we consider that a manufacturer invests in green technologies to produce products and sell them through a smart platform supply chain by an agency selling or reselling strategy, in which the platform provides data-driven marketing technology to promote green products. Four game models are constructed to study the operational efficiency of the platform supply chain considering selling strategy difference and government subsidy. The results show that: (1) The manufacturer's green technology and the platform's data-driven marketing levels, as well as all member's profits are all influenced by the potential market demand of green products, the sensitivities of consumers to green product attributes, and data analysis technology. (2) The service commission rate charged by the platform plays a main role on the manufacturer's selling strategy choice, when the service commission rate is low, the manufacturer chooses an agency selling strategy and can obtain more profit, but now the green technology level is not necessarily better than that in the reselling system. With the service commission rate increases, a manufacturer that chooses the reselling strategy can obtain more profit, and the green technology level is better than in the agency selling system. (3) Government subsidy can effectively encourage the manufacturer to improve the green technology level, and now the platform will improve the data-driven marketing level. There is a threshold range of the service commission rate charged by the platform in which the government can guide the manufacturer and the platform to reach an equilibrium selling strategy by regulating the subsidy level.

Keywords: supply chain management; online platform; green technology; data-driven marketing; government subsidy

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1. Introduction

The green R&D and production have gained more and more enterprise attention. Green behavior can meet consumers green preferences and government policies in the dilemma that the rapid development of the economy creates environmental problems and the deterioration of the global climate has become an important issue of concern to the international community. In practice, Haier Bio has been actively undertaking the corporate responsibility of green development, and the concept of green and green development runs through the whole process and chain of production and operation, constantly promoting the green transformation and upgrading of the enterprise. In the design process, carbon neutral design is adopted from the beginning of design to realize the energy-saving upgrade of products. In response to the national goal of carbon neutralization in 2045, "rapidly reduce green emissions, actively carry out carbon reduction work in the field of R&D", China Great Wall focuses on the three key areas of "energy saving green technology, green material application, energy reconstruction", and develops green vehicles to help China's environmental protection cause. At the same time, major political and legislative initiatives have been proposed to better incentivize enterprises' green activities. For example, The Paris climate Conference in 2016 resulted in a major intergovernmental agreement obliging signatory governments and government agencies to provide incentives in terms of financial or legislative assistance to support and scale up green products and technologies in different industries. Chinese President Xi Jinping announced at the Climate Ambition Summit sponsored by the United Nations and relevant countries that China will adopt more effective policies and measures, including subsidy for manufacturers based on the number of green and low-carbon products they produce and sell. Through subsidy, the government can stimulate manufacturers to increase investment in green technology and improve the greenness of products. For the above reasons, the areas about supply chain operation and government subsidy strategy for green R&D always are the research hotspots in theory and practice.

With the rapid development of the Internet and the digital economy, platform economy based on networking, digitalization, and smart technology is conducive to promoting the optimization and upgrading of industrial structure, improving user experience, flourishing various markets, improving the efficiency of resource allocation in the whole society, and injecting new vitality into the traditional economy. Enterprises gradually realize that platform is the core of supply chain system construction and development. It can give full play to its data advantages to reduce and eliminate carbon emissions in the operation process of the industrial chain. Therefore, it is important to study how the government guides manufacturers to participate in the operation of smart platform supply chain, and to invest in green technologies to improve ecological benefits while taking into account economic benefits. Platforms can provide two cooperative modes for manufacturers to sale products, agency selling, and reselling [1]. For example, JD.COM works with brands such as Huawei, Coach and Burberry under the reselling model, in which the brands sell their products to JD.COM at wholesale prices, which JD.COM sells to consumers at a markup. However, when JD.COM cooperates with Topsports, Sephora and other brands, it adopts the agent selling mode. By this way, the manufacture can sell products to consumers directly through the platform of JD.COM, and JD.COM charges a certain service commission fee (JD.COM public welfare, 2020). Amazon started with a reselling mode, as the mode developed, Amazon broke the reselling model which is similar to the entity retail model, and adopted an agency selling mode to help enterprises sell products directly to the terminal consumer. In addition, due to the platform's natural data collection advantages, the platform supply chain is based on data-driven analysis to describe, predict, analyze, and guide consumer behavior, providing better marketing activities for green products, that is data-driven marketing (DDM) [2,3]. For example, in September 2018, Taobao created a series of data-based and content-based targeted marketing programs for Shiseido, and established Shiseido's specific data center bank to provide data for marketing. In 2018, JD.COM adopted data-driven marketing to cooperate with many well-known brands in the industry, such as mobile phone brand Huawei, food brand Lang Jiu, and home appliance brand Bear. At the same time, data-driven marketing generates new types of costs, such as data collection costs and data analysis costs [4]. Research on the promotion effect of smart marketing level on green products can provide effective guidance and help for green R&D activities in reality. Operating platform supply chain can help enterprises to improve the efficiency of green technology investment activities and realize the overall development of economic and ecological benefits.

In this background, three questions must be answered: (1) How does the potential market demand of green products, the sensitivities of consumers to green product attributes and data analysis technology affect the levels of the manufacturer's green technology and the platform's data-driven marketing, as well as all member's profits in a platform supply chain system? (2) Which is the best strategy (the agency selling or reselling strategy) that can make higher levels of green technology and data-driven marketing, gaining more profit for all members, and how does the service commission rate affect the manufacturer's selling strategy choice? (3) Are government subsidies related to green technology conducive to the manufacturer to improve the level of green technology, and is it conducive to all members to obtain more profit, and how does the government subsidy affects the system members' choice about agency selling or reselling strategy?

In order to solve the above three questions, we construct a platform supply chain consisting of a manufacturer and a smart platform. The manufacturer invests in green technology to produce green products, while the smart platform invests in data-driven marketing technology to promote the sales of green products. The costs of green technology investment and data-driven marketing are borne by the manufacture and the platform, respectively. Furthermore, both the activities of the manufacturer's green R&D and the platform's data analysis have positive impacts on the demand of consumers with green preferences in the market. On this basis, we stand on the overall perspective of the platform supply chain system, and systematically analyze the impact of green technology and data-driven marketing interaction on the operational efficiency of the platform supply chain. Four game models of platform supply chain considering agency selling or reselling strategy without or with government subsidy are constructed to answer the above three questions.

Our theoretical analysis shows that: As the potential market demand scale of green consumers, the sensitivities of consumers to green product attribute, and data analysis technology increases, the unit selling price and sale quantities of green products, the levels of the manufacturer's green technology, and the smart platform's data analysis technology improves, and the profits of the manufacturer and the platform increases. The service commission rate charged by the smart platform affects the manufacturer's green technology level and profit, and then affect the manufacturer's selling strategy choice, which can also lead to the inconsistency of selling strategy choice between the manufacturer and the platform. Government subsidy can help the manufacturer improve the green technology level and are beneficial to the manufacturer and the platform to reach an agreement on the selling strategy choice. However, we have an interesting finding which is different from the existing achievements about traditional supply chain management with government subsidy. That is, when the government subsidy level is large, the manufacturer's behavior of reducing the unit selling price of green products will reduce the platform's commission fee, which is not conducive to the participation of the platform to sell green products. For this reason, the manufacturer should be moderately subsidized in a platform supply chain with agency selling strategy.

The rest of this paper is organized as follows: We give the literature review about green supply chain management and platform supply chain management in Section 2. Section 3 contain the model description and assumptions. In Section 4, the basic agency selling and reselling models without government subsidy are given to analysis the effects of the potential market demand of green products, the sensitivity of consumers to green product attributes and data analysis technology, and in this section, we also analyze the agency selling and reselling strategies which are better to all members' profits and the manufacturer's green technology level. In Section 5, we construct agency selling and reselling platform supply chain models with government subsidy to analysis the effect of government subsidy on the levels of green technology and data-driven marketing, and all members' profits, and how the government subsidy affects the equilibrium selling strategy. Finally, Section 6 provides the conclusions.

2. Literature Review

This paper focuses on the problems about green supply chain management in the era of platform economy. Thus, the related literature are mainly about green supply chain management and platform supply chain management.

2.1. ESG and Green Supply Chain Management

Sustainable and green activities can help improve enterprises' environmental, social and governance (ESG) performance, which has been proved by some scholars from an empirical perspective. For example, Husted et al. [5] use ESG data of 459 enterprises from nine countries to analyze and find that sustainable governance can improve ESG performance. Wang et al. [6] conduct an annual observation sample study of 1980 enterprises from the top 500 green companies in the United States from 2009 to 2013 and point out that green activities of enterprises had significant effects on their social responsibility fulfillment and financial performance improvement. Yang et al. [7] confirmed that clean energy, green finance, and economic development are important and positive signs for sustainable practices based on G7 sustainable economies from 2010 to 2018. Tan et al. [8] investigated the impact of ESG rating on enterprise green innovation based on data related to Chinese A-share listed companies from 2010 to 2018, and showed that ESG rating can significantly promote the quantity and quality of enterprise green innovation.

Based on the ESG concepts and measures proposed by the above achievements, we know that green production and operation activities from the perspective of supply chain can well achieve the goal of balancing economic growth and environmental protection. In 1996, scholars from Michigan State University proposed the embryonic form of green supply chain management theory. Subsequently, some scholars put forward the idea that green supply chain management is sustainable and ecological management [9–11]. Nagel [12] showed that green procurement is an extremely important driving factor in green supply chain management, and environmental awareness should penetrate every link of the supply chain. Hall et al. [13] believed that green supply chain management is an effective way for enterprises to bear environmental pressure and put environmental innovation concept through the whole supply chain process, to realize environmental protection. Zsidisin et al. [14] researched how green supply chain management integrates green environmental awareness into the whole process of product manufacturing and recycling to carry out environmental management. Tachizawa et al. [15] explored how green supply chain management can improve environmental benefits and maximize resource utilization as the goal. Rahmani et al. [16] defined green supply chain management as considering the necessity of environment and paying attention to ecological benefits in product design, material supply, processing, transportation, and product recycling and reuse interaction. Nekmahmud et al. [17] systematically combed the literatures about green supply chain management and identify the obstacles and key factors of implementing green supply chain management. Hariharasudan et al. [18] assessed how green supply chain management is still the focus of scholars' attention and plays an important role in changing environmental issues. Astawa et al. [19] discovered that the practice of green supply chain management has positive impact on the performance and competitive advantage of five-star hotels by conducting analysis of 145 respondents. Kot et al. [20] investigated the supply chain management practices of 613 small and medium-sized enterprises around the world, and found that environmental and social sustainability are the shutdown factors that can affect supply chain management performance. The above scholars published their research on green supply chain management from different industries and perspectives, and some scholars discuss the operation management of green supply chain from the perspective of manufacturers' green R&D activities and consumers' participation. For example, Liu et al. [21] studied whether suppliers invest in carbon emission reduction and establish a decision-making model for green agricultural supply chain. The results showed that cooperation between manufacturers and retailers can achieve the goal of protecting environment and members' profits. Ma et al. [22] believed that green supply chain management is an environmental management mode to attract consumers to carry out green consumption through manufacturers' green emission reduction technologies, thus alleviating the global environmental crisis. Zhu et al. [23] studied the design and development of green products in competitive environment and found that price competition can make the greenness of products increase and promote green R&D activities.

Hong et al. [24] discussed the design and development of green products in a two-echelon supply chain by taking consumer reference behavior as a reference point, and the results showed that consumers' green awareness play a positive role on green R&D.

In order to encourage enterprises to improve green technology investment level and promote sustainable economic development, the government can provide green subsidy and standard for enterprises' technology investment [25,26], which can motivate members and consumers in the supply chain to obtain more benefits and improve their enthusiasm to fulfill social responsibilities [27]. Yang et al. [28] analyzed the impact of government subsidy on technological innovation of competitive enterprises and found that government subsidy can alleviate the prisoner's dilemma between the two competitive enterprises and improve their profits. Gao et al. [29] assessed the improvement of green R&D technology and how it can continuously improve the environmental benefits of development-intensive green products considering government sets green standards. Xue et al. [30] analyzed the decision making of the green supply chain with energy-saving products, and they found that the government subsidy is positively correlated with the energy-saving level, product price and market demand, which could significantly improve social welfare and promote the improvement of energy-saving products. Li et al. [31] investigated the impact of government subsidy on the innovation level of secondary supply chain, and the results showed that consumer subsidy is more effective than producer subsidy in promoting innovation investment. Ma et al. [22] considered that under government intervention, manufacturers invest in green emission reduction technology to reduce carbon emissions, and retailers invest in information technology to deliver green quality of products to consumers. This study also shows that higher emission reduction subsidy encourages investment in green emission reduction technology and makes all members' profits increase. Chen et al. [32] researched the impact of government subsidy policies on collaborative innovation in a two-layer supply chain, and found that government subsidy helps improve innovation efficiency. In addition, other scholars discussed the limited government budget and sufficient government budget [33,34], the government's subsidy scheme for green technology in competitive manufacturing [35], the different channel structure with government subsidy [36], the government's subsidy to supply chain members through linear subsidy and fixed subsidy [37], how the government allocates special subsidies between consumers and manufacturers [38,39], etc., to subsidize members in supply chain and carry out green R&D and production management.

The above research demonstrates the benefits to enterprises who carry out green supply chain operation activities on improving economic and ecological benefits and also indicates that consumers' green awareness and government green subsidy are important. However, all of these papers research traditional supply chain, there are fewer studies research green supply chain management with platform selling.

2.2. Platform Supply Chain Management

The Internet platform provides a new way of communication for enterprises and consumers and provides a new marketing channel for manufacturers. The introduction of e-commerce platforms can lead to an increase in product market demands with lower selling price and help both the manufacturer and the platform gain more income [40–42]. The platform supply chain management has become the focus of scholars' research. Platform has clear effects on improving the operation efficiency of supply chain through data analysis technology. For example, the platform can give full play to the advantages of data intelligence, reduce the procurement cost of supply chain [43], and help members in the supply chain to obtain more benefits based on the increase in product demand with mining consumer preferences and data-driven marketing (DDM) technology [42–44], improve the coordination and cooperation level among supply chain members [45] and innovation level [46,47]. The above platform supply chain papers show the advantages that platforms can improve the market demands and members' profits by data analysis technology, such as data-driven marketing (DDM).

Because platforms can generally provide agency selling or reselling strategies for manufacturers and retailers, many scholars have conducted studies about the problem of members selling strategy choice. For example, Xiao et al. [48] investigated the motivation of retailers to accept digital empowerment of the platform and join the platform, and proposed that the platform with the operation data of each retail store can effectively help retailers select suitable products, thus improving their operation efficiency. Hao et al. [49] assessed the publishing industry, considered the complementary relationship between products and devices, studied the pricing of e-books and e-book readers under wholesale and agency pricing modes, and summarized that due to the existence of the complementary market (i.e., e-book readers), the price of e-books in the pure reselling mode is low. Hagiu et al. [1] assumed information asymmetry among supply chain members and analyzed the problem of marketing activity level on the selection of supplier's selling mode. The agency selling mode and reseller mode depends on more useful information to optimize customized marketing activities for each specific product. Young [50] studied the influence of online review information of third-party consumers on equilibrium selling strategies in a platform supply chain. Abhishek et al. [51] constructed a supply chain model with one manufacturer and two platforms and analyzed the positive or negative cross-channel effect and competitive intensity and other factors on agency selling or reselling modes choice. Tan et al. [52] proved that the mechanism of online market (i.e., agency selling) can benefit both upstream suppliers and retailers in the digital publishing industry by comparing the profits of manufacturers, platforms, and consumer welfare of agency selling and reselling models in the sale of digital products. Tan et al. [53] showed that the agency model is beneficial to the sales of digital products due to the revenue-sharing structure and the direct control of price by upstream publishers by studying the choice between agency model and wholesale model when digital goods are sold on online platforms. Tian et al. [54] considered a platform supply chain composed of a retailer and a platform (such as Amazon platform) and analyzed when Amazon allows retailers to sell products on its platform. Zhang et al. [55] considered whether manufacturers add the number of offline stores when selling products through online retailers. This paper discusses whether online retailers with demand information share information with manufacturer, and which selling modes (agency selling and reselling) manufacturers choose. Chen et al. [56] found that the reselling mode is no longer a win-win strategy in competitive conditions, and a mixture of reselling and agency selling modes can realize the pareto improvement. Tan [57] analyzed the agency mode of digital products based on the digital product industry. Geng [58] discussed the additional product pricing of the upstream manufacturers and downstream online platform of the interaction between selling mode selection, and found that when the platform of the service commission rate is not too low and additional product under the condition of market potential is not too big, platforms will choose the agency selling mode. Wei et al. [59] considered the comprehensive effects of manufacturers' leader-follower relationship and platform retailers' recommendation fees to help the manufacturers choose agency selling or reselling mode to sell products in e-commerce platforms. From the above literature review, we can see that manufactures and the platforms may chose different selling strategies for conditional differences. However, there is a lack of papers about green product R&D and selling in the operation process of platform supply chain.

2.3. Research Gaps

From the above literature review, we can find rich achievements about green supply chain management and platform supply chain management. These papers highlight the benefits and advantages of green R&D and online platform selling activities, respectively. However, there is a research gap about the integration of green platforms to carry out supply chain operation management. At present, Xu and Zhang [60] and Yang et al. [61] have studied the issue of manufacturers' R&D and production of green products for sales under the environment of online channels, and proved that the introduction of online channels helps to improve the greenness of products and the profits of each member, but these literatures only consider the direct sales of products by manufacturers through platforms and do not consider the cooperation mode of agency selling and reselling strategy between the manufacturer and the online platform, as well as the problems of platforms conducting data-driven marketing. Considering that platforms have broad selling market and data analysis advantages, we construct game models of the platform supply chain under agency selling or reselling strategies, respectively, and study the impact of data-driven marketing on manufacturer's green technology level. On this basis, the government subsidy models are also constructed to further explore the impact of government policies on the operational efficiency of the platform supply chain to better achieve win-win economic and ecological benefits. The theoretical models presented in this paper can enrich the frontier crossover theory of green and platform supply chain.

3. Model Description and Assumptions

In a supply chain composed of a manufacturer (he) and a smart platform (she), the manufacturer invests in green technology to produce green products and sells them through a smart platform by selecting agency selling or reselling strategy. Under these two selling strategies, the smart platform carries out data-driven marketing (DDM) activities for selling products. That is, she uses the information of consumer green preferences to carry out precision marketing. Agency selling strategy means that the manufacturer directly sells products through the smart platform after paying the service commission fee. Reselling strategy refers to that the manufacturer wholesales the product to the platform and then the platform sells the product to the consumers, that is, the platform plays the role of the retailer, such as Tmall, JD.COM, Amazon, and other enterprises that can provide the above selling strategy. The operation process of the platform supply chain under the agency selling and reselling strategies are shown in Figure 1. In order to encourage the manufacturer to invest in green technology, the government shall subsidize the manufacturer. The operation process of the platform supply chain under the agency selling and reselling strategies considering government subsidy are shown in Figure 2.

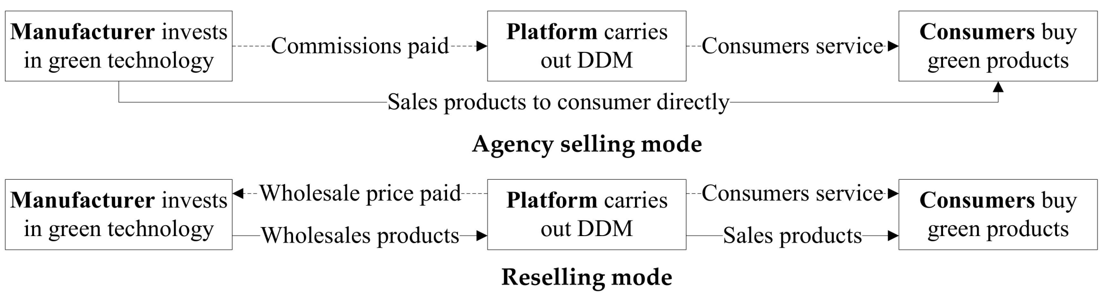

Figure 1. The operation process of platform supply chain with green technology investment and data-driven marketing (DDM).

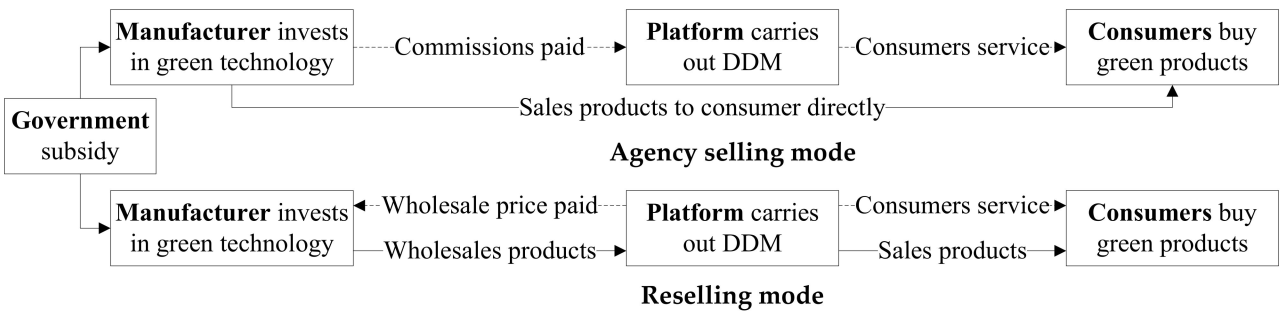

Figure 2. The operation process of platform supply chain with green technology investment and data-driven marketing (DDM) considering government subsidy.

Assumption 1. *Both the manufacturer and the smart platform are rational, and the smart platform is the leader and the manufacturer is the follower.*

Assumption 2. *The manufacturer invests in green technology to produce green products, the green technology level is e. Because of the new technology, investments are often diseconomies of scale, we set the cost of the manufacturer's green technology investment to produce green products is* $e^2/2$*, which is relative to the green technology level e. In order to analyze the impact of green technology, without loss of generality, the unit production cost of green products can be normalized to zero [32].*

Assumption 3. *The platform provides an agency selling or reselling strategy to sell the manufacturer's green products. (1) Under the agency selling strategy, the service commission fee paid by the manufacturer to the smart platform is* ηp, $\eta(0 < \eta < 1)$*, the service commission rate and p is the unit selling price of green products directly sold by the manufacturer through the platform [51]. (2) Under the reselling strategy, the manufacturer sells green products to the platform at the unit wholesale price w, and the platform raises the price m of each unit of green products and sells them to consumers at the unit selling price* $p = w + m$*. At the same time, the platform owns consumers data, she can use data analysis technology mining green preference information from consumers, such as consumer browsing and purchase behavior in evidence data, then can carry out consumer green product precision marketing activities, increase the market demand of green products. We call this the data-driven marketing (DDM). The data-driven marketing level of the smart platform is t, we set the cost of the investment about data-driven marketing level is* $t^2/2$ [42].

Assumption 4. *To encourage the manufacturer to invest in green technology, the government shall subsidize the unit price of green products produced by the manufacturer with s. For example, China State Council decided to provide 26.5 billion yuan in subsidy for a series of home appliances, including air conditioners and flat-panel televisions, that meet energy-saving standards.*

Assumption 5. *The market demand for green products is* $q = \alpha - p + ke + \sigma t$*. Where* α *is the potential market demand of green products,* $k(0 < k < 1)$ *is the sensitivity coefficient of consumers to green product attribute (that is the green technology level), and* $\sigma(0 < \sigma < 1)$ *is the sensitivity coefficient of consumers to data analysis technology (that is the data-driven marketing level).*

Decision variables are expressed as follows: green technology level e^i, unit wholesale price w^i, data-driven marketing level t^i, unit selling price of green product to consumers p^i. Where $i = NA, NR, HA, HR$ respectively represents agency selling strategy without government subsidy, reselling strategy without government subsidy, agency selling with government subsidy, and reselling strategy with government subsidy. The profit function of each member in the smart platform supply chain is expressed as π_j^i. Where $j = M, P$ respectively represents the manufacturer and the platform. Further superscript "*" in decision variable and member profit function refers to equilibrium solution.

4. The Basic Models: Results and Discussions

4.1. Agency Selling Mode

The profit functions of the manufacturer and the smart platform are as follows:

$$\pi_M^{NA}(p,e) = (1-\eta)pq - \frac{1}{2}e^2 \quad (1)$$

$$\pi_P^{NA}(t) = \eta pq - \frac{1}{2}t^2 \quad (2)$$

When the manufacturer sells green products on an agency selling platform supply chain, he determines the green technology level and direct selling price of green products according to the service commission rate which is set by the platform. Then, the platform determines the data-driven marketing level for the green products. The equilibrium decisions of the manufacturer and the platform can be obtained as shown in proposition 1 with backward induction method. Please see Appendix A for detailed proof process.

Proposition 1. *The equilibrium decisions of the agency selling platform supply chain are:* $p^{NA*} = \frac{\alpha\left[2-k^2(1-\eta)\right]}{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2}$, $q^{NA*} = \frac{\alpha\left[2-k^2(1-\eta)\right]}{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2}$, $e^{NA*} = \frac{\alpha k(1-\eta)\left[2-k^2(1-\eta)\right]}{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2}$, $t^{NA*} = \frac{2\alpha\eta\sigma}{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2}$, $\pi_M^{\text{NA}*} = \frac{\alpha^2(1-\eta)\left[2-k^2(1-\eta)\right]^3}{2\left[\left(2-k^2(1-\eta)\right)^2-2\eta\sigma^2\right]^2}$, $\pi_P^{\text{NA}*} = \frac{\alpha^2\eta}{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2}$.

Based on the equilibrium decisions of the manufacturer and the platform in proposition 1, we can further analyze the impacts of the parameters of consumers' market demand, the sensitivity coefficients about green technology and data-driven marketing, and the service commission on all members' decisions and profits. Please see Conclusion 1 and Appendix B for detailed proof process.

Conclusion 1. *The impacts of the potential market demand of green products, the sensitivity coefficients of consumers to green product attributes and data analysis technology, and the service commission rate on the equilibrium decisions of agency selling system are as follows: (1)* $\frac{\partial p^{NA*}}{\partial\alpha} > 0$, $\frac{\partial q^{NA*}}{\partial\alpha} > 0$, $\frac{\partial e^{NA*}}{\partial\alpha} > 0$, $\frac{\partial t^{NA*}}{\partial\alpha} > 0$, $\frac{\partial \pi_M^{NA*}}{\partial\alpha} > 0$, $\frac{\partial \pi_P^{NA*}}{\partial\alpha} > 0$, $\frac{\partial p^{NA*}}{\partial k} > 0$, $\frac{\partial q^{NA*}}{\partial k} > 0$, $\frac{\partial e^{NA*}}{\partial k} > 0$, $\frac{\partial t^{NA*}}{\partial k} > 0$, $\frac{\partial \pi_M^{NA*}}{\partial k} > 0$, $\frac{\partial \pi_P^{NA*}}{\partial k} > 0$, $\frac{\partial p^{NA*}}{\partial\sigma} > 0$, $\frac{\partial q^{NA*}}{\partial\sigma} > 0$, $\frac{\partial e^{NA*}}{\partial\sigma} > 0$, $\frac{\partial t^{NA*}}{\partial\sigma} > 0$, $\frac{\partial \pi_M^{NA*}}{\partial\sigma} > 0$, $\frac{\partial \pi_P^{NA*}}{\partial\sigma} > 0$. *(2)* $\frac{\partial p^{NA*}}{\partial\eta} > 0$, $\frac{\partial q^{NA*}}{\partial\eta} > 0$, $\frac{\partial e^{NA*}}{\partial\eta} < 0$, $\frac{\partial t^{NA*}}{\partial\eta} > 0$, *if* $\sigma < \sqrt{\frac{\left[2-k^2(1-\eta)\right]^2}{2\left[2-\eta-k^2(1-\eta^2)\right]}}$, $\frac{\partial \pi_M^{NA*}}{\partial\eta} < 0$, *and elseif* $\sigma > \sqrt{\frac{\left[2-k^2(1-\eta)\right]^2}{2\left[2-\eta-k^2(1-\eta^2)\right]}}$, $\frac{\partial \pi_M^{NA*}}{\partial\eta} > 0$.

In the agency selling platform supply chain, conclusion 1 shows that:

1. When the potential market demand of green products increases, it can be known from the market demand function of green products that the number of consumers willing to buy green products will increase, and the manufacturer should raise the unit selling price of green products. It will also encourage the manufacturer to invest more in green technology level, which will make more potential consumers willing to buy green products. At this point, although the cost of green technology investment increases, the increases of market demand and unit selling price of green products will bring more revenue to the manufacturer than the increase in the cost of green technology investment, so the manufacturer's profit increases. At the same time, the potential market demands of green products increase, which inspires the smart platform to improve the data-driven marketing level, this will make the market demands of green products increase, and with the increase in the unit selling price of green products, the smart platform can get more revenue from the service commission fee than the increasing cost of data-driven marketing. Therefore, the profit gained by the smart platform under the agency selling strategy will also increase. When the sensitivity coefficients of consumers to green products attributes and the data analysis technology increase, it can be seen from the market demand function of green products that the number of consumers willing to buy green products directly increases and the same result will be produced. Therefore, through publicity and promotion, the government and enterprises can popularize the concept of green consumption to more consumers and improve their awareness of green consumption, which will help the manufacturer better carry out green technology investment activities and the smart platform enterprises more effectively promote green products to consumers through data analysis technology.
2. When the service commission rate charged by the smart platform increases, in order to obtain more service commission, she should increase the market demand of green products by improving her data-driven marketing level. At this point, the increase in her service commission fee is greater than the increase in the cost of data analysis technology, so her profit increases. At the same time, for the manufacturer, he should raise the unit selling price of green products, and in order to neutralize more service commission fee, the manufacturer should reduce the green technology level to lower

related cost. However, if consumers are insensitive to data analysis technology, the improvement of data-driven marketing level of smart platform will not make the market demand of green products increase, so the increase in the manufacturer's income is less than the increase in the service commission fee, so his profit decrease. If consumers are sensitive to data analysis technology, the improvement of data-driven marketing level of smart platform will make the market demand of green products increase greatly, so the increase in the manufacturer's income is greater than the increase in the service commission fee, so his profit increases. Therefore, it can be seen that the manufacturer can better conduct green investment activities by avoiding the high service commission rate charged by the smart platform and improving consumers' sensitivity to data analysis technology of smart platform.

4.2. Reselling Mode

The profit functions of the manufacturer and the smart platform are as follows:

$$\pi_M^{NR}(w,e) = wq - \frac{1}{2}e^2 \quad (3)$$

$$\pi_P^{NR}(p,t) = (p-w)q - \frac{1}{2}t^2 \quad (4)$$

When the manufacturer resells green products in reselling platform supply chain, he determines the green technology level and unit wholesale price of green products. Then, the platform determines the data-driven marketing level and unit selling price of green products. The equilibrium decisions of the manufacturer and the platform can be obtained as shown in Proposition 2 with backward induction method.

Proposition 2. *The equilibrium decisions of the reselling platform supply chain are:* $w^{NR*} = \frac{\alpha}{4-\sigma^2-2k^2}$, $m^{NR*} = \frac{\alpha(2-k^2)}{4-\sigma^2-2k^2}$, $p^{NR*} = \frac{\alpha(3-k^2)}{4-\sigma^2-2k^2}$, $q^{NR*} = \frac{\alpha}{2(2-k^2)-\sigma^2}$, $e^{NR*} = \frac{\alpha k}{4-\sigma^2-2k^2}$, $t^{NR*} = \frac{\alpha\omega}{4-\sigma^2-2k^2}$, $\pi_M^{NR*} = \frac{\alpha^2(2-k^2)}{2[2(2-k^2)-\sigma^2]^2}$, $\pi_P^{NR*} = \frac{\alpha^2}{2[2(2-k^2)-\sigma^2]}$.

Based on the equilibrium decisions of the manufacturer and the platform in proposition 2, we can further analyze the impacts of the parameters of consumers' market demand and the sensitivity coefficients about green technology and data-driven marketing on all members' decisions and profits. Please see Conclusion 2.

Conclusion 2. *The impacts of the potential market demand of green products, the sensitivity coefficients of consumers to green product attributes and data analysis technology on the equilibrium decisions of reselling system are as follows:* $\frac{\partial w^{NR*}}{\partial \alpha} > 0$, $\frac{\partial p^{NR*}}{\partial \alpha} > 0$, $\frac{\partial q^{NR*}}{\partial \alpha} > 0$, $\frac{\partial t^{NR*}}{\partial \alpha} > 0$, $\frac{\partial e^{NR*}}{\partial \alpha} > 0$, $\frac{\partial \pi_P^{NR*}}{\partial \alpha} > 0$, $\frac{\partial \pi_M^{NR*}}{\partial \alpha} > 0$, $\frac{\partial w^{NR*}}{\partial k} > 0$, $\frac{\partial p^{NR*}}{\partial k} > 0$, $\frac{\partial q^{NR*}}{\partial k} > 0$, $\frac{\partial e^{NR*}}{\partial k} > 0$, $\frac{\partial t^{NR*}}{\partial k} > 0$, $\frac{\partial \pi_P^{NR*}}{\partial k} > 0$, $\frac{\partial \pi_M^{NR*}}{\partial k} > 0$, $\frac{\partial w^{NR*}}{\partial \sigma} > 0$, $\frac{\partial p^{NR*}}{\partial \sigma} > 0$, $\frac{\partial q^{NR*}}{\partial \sigma} > 0$, $\frac{\partial e^{NR*}}{\partial \sigma} > 0$, $\frac{\partial t^{NR*}}{\partial \sigma} > 0$, $\frac{\partial \pi_P^{NR*}}{\partial \sigma} > 0$, $\frac{\partial \pi_M^{NR*}}{\partial \sigma} > 0$.

In the reselling platform supply chain system, conclusion 2 shows that:

When the potential market demand of green products increases, the number of consumers willing to buy green products increases, and the manufacturer should raise green technology levels to attract more consumers to buy green products. At the same time, the smart platform improves the data-driven marketing level to explore more potential consumers to buy green products. In order to gain more revenue, the manufacturer should raise the unit wholesale price of green products, and the smart platform should raise the unit selling price of green products. Therefore, for the manufacturer, the increase in market demand and unit selling price of green products will bring more revenue to the manufacturer than the increase in green investment costs, so the manufacturer's profit increases. For the smart platform, the increases of market demand and unit selling price of green products make her revenue increase more than the increase in the costs about data-driven marketing and wholesale. Therefore, the profit obtained by the smart platform under reselling strategy will also increase. When the sensitivity coefficients of consumers to the green product attributes and data-driven marketing level increases, it can be seen from the market demand function of green products that the number of consumers willing to buy green products directly increases and the same result will be produced. Therefore, the same as to the agency selling system, the government and enterprises should popularize the concept of green consumption to consumers and improve their awareness of green consumption under the reselling strategy.

4.3. Selling Strategy Analysis

Theorem 1. *Comparing the equilibrium decisions of agency selling and reselling platform supply chain, we can find that: (1) if* $(1-\eta)\left[2-k^2(1-\eta)\right]^3\left[2\left(2-k^2\right)-\sigma^2\right]^2-\left(2-k^2\right)\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}^2>0$, $\pi_M^{\mathrm{NA}*}>\pi_M^{NR*}$, *and elseif* $(1-\eta)\left[2-k^2(1-\eta)\right]^3\left[2\left(2-k^2\right)-\sigma^2\right]^2-\left(2-k^2\right)\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}^2<0$, $\pi_M^{\mathrm{NA}*}<\pi_M^{NR*}$. *(2) if* $\eta<\eta_1$, $\pi_P^{\mathrm{NA}*}<\pi_P^{NR*}$, *and elseif* $\eta>\eta_1$, $\pi_P^{\mathrm{NA}*}>\pi_P^{NR*}$. *(3) if* $\eta<\eta_2$, $e^{NA*}>e^{NR*}$, *and elseif* $\eta>\eta_2$, $e^{NA*}<e^{NR*}$. *(4) if* $\eta<\eta_1$, $t^{NA*}<t^{NR*}$, *and elseif* $\eta>\eta_1$, $t^{NA*}>t^{NR*}$. *(5)* $q^{NA*}>q^{NR*}$. *(6)*$p^{NA*}<p^{NR}$. $\eta_1=\frac{\left(2-k^2\right)^2-2\left(2-k^2\right)\sqrt{1-k^2}}{k^4}$, $\eta_2=\frac{\left[\left(2-k^2\right)-\sigma^2\right]\left(2-k^2\right)-\sqrt{2\left(2-\sigma^2\right)\left(2-k^2\right)\left[\left(2-k^2\right)-\sigma^2\right]}}{k^4+\sigma^2k^2-4k^2}$.

Please see Appendix C for detailed proof process about Theorem 1.

In the agency selling or reselling platform supply chain system, theorem 1 shows that:

The service commission rate charged by the smart platform plays a major role on the manufacturer's choice of selling strategy. (1) When the service commission rate is low, the manufacturer tends to choose the agency selling strategy, because under this strategy, the manufacturer can direct sales products, compared with the smart platform selling green products under the reselling strategy, the manufacturer can sell more green products at a lower price. At the same time, the manufacturer will have a high green technology level, which can further increase the market demand for green products and bring a further increase in the manufacturer's revenue. Therefore, when the service commission rate is low, the manufacturer should choose the agent selling strategy. As the service commission rate increases, the manufacturer should choose the reselling strategy. This is because it can be seen from proposition 1 that the manufacturer's profit will be lower than the reselling strategy because it bears more service commission fee, so the manufacturer should choose the reselling strategy. (2) For the smart platform, when the service commission rate is low, the profit will be lower than that of the reselling strategy. With the increase in the service commission rate, the smart platform's profit under the agency selling strategy will exceed that in the reselling system. To sum up, the manufacturer and the smart platform should have inconsistent choice of selling strategy. Therefore, the question is whether there is a threshold value for the service commission rate charged by the smart platform to make all members reach a consensus on the choice of selling strategy, and whether the government subsidy can encourage the two and reach a consensus on the choice of selling strategy. We will provide the answer in the analysis of numerical examples in Section 5.

5. The Government Subsidy Models

5.1. Agency Selling Mode

The profit functions of the manufacturer and the smart platform are as follows:

$$\pi_M^{HA}(p,e)=(1-\eta)pq+sq-\frac{1}{2}e^2 \tag{5}$$

$$\pi_P^{HA}(t) = \eta pq - \frac{1}{2}t^2 \quad (6)$$

When the manufacturer sells green products in an agency selling platform supply chain with government subsidy, he determines the green technology level and the direct selling price of green products according to the service commission rate which is set by the platform. Then, the platform determines the data-driven marketing level for the green products. The equilibrium decisions of the manufacturer and the platform can be obtained as shown in proposition 3 with backward induction method.

Proposition 3. *The equilibrium decisions of the platform supply chain under the agency selling strategy with government subsidy are:* $p^{HA*} = \frac{\alpha(1-\eta)+k^2(1-\eta)s-s}{2(1-\eta)-k^2(1-\eta)^2} + \frac{\eta\sigma^2(2\alpha+ks)}{[2-k^2(1-\eta)]\left\{[2-k^2(1-\eta)]^2-2\eta\sigma^2\right\}}$, $q^{HA*} = \frac{\left[\alpha(1-\eta)+sk^2(1-\eta)-ks(1-\eta)+s\right]\left\{[2-k^2(1-\eta)]^2-2\eta\sigma^2\right\}+(1-\eta)\left(2\alpha+k^2s\right)\eta\sigma^2}{(1-\eta)[2-k^2(1-\eta)]\left\{[2-k^2(1-\eta)]^2-2\eta\sigma^2\right\}}$, $e^{HA*} = k\frac{[2-k^2(1-\eta)][\alpha(1-\eta)+s]-\eta\sigma^2 s}{[2-k^2(1-\eta)]^2-2\eta\sigma^2}$, $t^{HA*} = \frac{\eta\sigma\left(2\alpha+k^2s\right)}{[2-k^2(1-\eta)]^2-2\eta\sigma^2}$, $\pi_M^{HA*} = \frac{\left(2-(1-\eta)k^2\right)\left\{\left[2-(1-\eta)k^2\right][s+(1-\eta)\alpha]-s\sigma^2\eta\right\}^2}{2(1-\eta)\left\{[2-k^2(1-\eta)]^2-2\eta\sigma^2\right\}^2}$, $\pi_P^{HA*} = \eta\frac{\left[2k^2(1-\eta)+\eta\sigma^2-2\right]s^2+2\alpha k^2(1-\eta)^2 s+2\alpha^2(1-\eta)^2}{2(1-\eta)^2\left\{[2-k^2(1-\eta)]^2-2\eta\sigma^2\right\}}$.

Conclusion 3. *In order to make the unit selling price of green products and the smart platform's profit positive, government subsidy need to be satisfied:* $s < \frac{\alpha(1-\eta)\left[2-k^2(1-\eta)\right]^2}{[2-k^2(1-\eta)]^2[1-k^2(1-\eta)]-\eta\sigma^2[2+k(1-2k)(1-\eta)]}$ *and* $s < \alpha(1-\eta)\frac{k^2(1-\eta)+\sqrt{4+k^2[k^2(1-\eta)-4](1-\eta)-2\eta\sigma^2}}{2-2k^2(1-\eta)-\eta\sigma^2}$, *so we set* $s < \min\left\{\frac{\alpha(1-\eta)\left\{\left[2-k^2(1-\eta)\right]\right\}^2}{[2-k^2(1-\eta)]^2[1-k^2(1-\eta)]-\eta\sigma^2[2+k(1-2k)(1-\eta)]}, \alpha(1-\eta)\frac{k^2(1-\eta)+\sqrt{4+k^2(1-\eta)[k^2(1-\eta)-4]-2\eta\sigma^2}}{2-2k^2(1-\eta)-\eta\sigma^2}\right\}$. *In the agency selling platform supply chain with government subsidy, conclusion 3 show that:*

Under the agency selling strategy, the government gives the manufacturer a certain amount of subsidy per unit of product, which will motivate the manufacture lower the unit selling price of green products. When government subsidy reaches a certain level, the manufacturer can get enough profit from the subsidy, and he will make the unit selling price of green products too low. At this time, the smart platform mainly gains profit through the service commission fee from the manufacturer. If the unit selling price of green products is too low, the income of the smart platform is less than the cost of her data-driven marketing, and the smart platform will quit the supply chain operation. Therefore, the government should not subsidize the manufacturer too much to ensure that the smart platform is profitable in agency selling platform supply.

Based on the equilibrium decisions of the manufacturer and the platform in proposition 3, we can further analyze the impacts of the parameters of government subsidy on all members' decisions and profits. Please see Conclusion 4.

Conclusion 4. *The impact of the government subsidy on the equilibrium decisions of agency selling platform supply chain with government subsidy are as follows:* $\frac{\partial p^{HA*}}{\partial s} < 0$, $\frac{\partial q^{HA*}}{\partial s} > 0$, $\frac{\partial e^{HA*}}{\partial s} > 0$, $\frac{\partial t^{HA*}}{\partial s} > 0$, $\frac{\partial \pi_M^{HA*}}{\partial s} > 0$. *if* $s < \frac{\alpha k^2(1-\eta)^2}{2-2k^2(1-\eta)-\sigma^2\eta}$, $\frac{\partial \pi_P^{HA*}}{\partial s} > 0$, *and elseif* $s > \frac{\alpha k^2(1-\eta)^2}{2-2k^2(1-\eta)-\sigma^2\eta}$, $\frac{\partial \pi_P^{HA*}}{\partial s} < 0$.

In the agency selling platform supply chain with government subsidy, conclusion 4 shows that:

Government subsidy can motivate the manufacturer to improve the green technology level and reduce the unit selling price of green products, which will help the market demand of green products increase. In order to cope with the negative impact of lower unit selling price of green products on the service commission fee, the smart platform should improve data-driven marketing level and further increase market demand of green products, to ensure the income from service commission. The increase in the manufacturer's income brought by government subsidy and the increase in market demand of green products is more than the decrease in income brought by the increase in cost of green technology investment and the decrease in unit selling price of green products, so the manufacturer's profit increases. However, when the government subsidy is less, for the smart platform, because the increase in market demand of green products makes its revenue increase more than the increase in data-driven marketing cost and the decrease in revenue brought by the decrease in unit sales price of green products, the smart platform's profit increase. When the government subsidy is high, the behavior of the manufacturer setting low unit selling price of green products will greatly reduce the service commission income of smart platform and her profits. It can be seen that government subsidy certainly can motivate manufacturer to improve green technology level and are favorable to get more profit for him, but a large degree of government subsidy will injure the smart platform's profit.

Theorem 2. *Comparing the equilibrium decisions of agency selling platform supply chain with and without government subsidy, we can find that: (1) if* $\sigma > \sqrt{\frac{2(1-k^2(1-\eta))s^2-2\alpha(1-\eta)^2(sk^2+\alpha(1-\eta))}{\eta s^2}}$, $\pi_P^{HA*} > \pi_P^{\mathrm{NA}*}$, *and elseif* $\sigma < \sqrt{\frac{2(1-k^2(1-\eta))s^2-2\alpha(1-\eta)^2(sk^2+\alpha(1-\eta))}{\eta s^2}}$, $\pi_P^{HA*} < \pi_P^{\mathrm{NA}*}$. *(2)*$\pi_M^{HA*} > \pi_M^{\mathrm{NA}*}$. *(3)*$e^{HA*} > e^{NA*}$. *(4)*$t^{HA*} > t^{NA*}$. *(5)*$p^{HA*} < p^{NA*}$. *(6)*$q^{HA*} > q^{NA*}$.

Please see Appendix C for detailed proof process about Theorem 2.

In the agency selling platform supply chain with or without government subsidy, we can find by combining conclusion 4 with theorem 2:

With government subsidy increases, the manufacturer reduces the unit selling price of green products while increasing the green technology level, which makes the market demand of green products and the manufacturer's profit increase. Therefore, under government subsidy, the unit selling price of green products is lower than that in the platform system without government subsidy, and the market demand of green products, the green technology level and the manufacturer's profit are all higher than these in the platform system without government subsidy. At this point, in order to cope with the negative impact of lower unit selling price of green products on the service commission fee, the smart platform should improve their data-driven marketing level to increase market demand of green products and ensure the income from service commission. (1) If consumers are more sensitive to data analysis technology, the market demand of green products will increase significantly, so the smart platform's profit will be higher than that in the platform system without government subsidy. Under the agency selling strategy, government subsidy can effectively motivate the manufacturer to invest in green technology. However, for the smart platform, whether she make profits depends on how the sensitive of consumers to data analysis technology. (2) If consumers are insensitive to data analysis technology, the market demand of green products will not increase much, so the smart platform's profit will be lower than that in the platform system without government subsidy.

5.2. Reselling Mode

The profit functions of the manufacturer and the smart platform are as follows:

$$\pi_M^{HR}(w,e) = wq + sq - \frac{1}{2}e^2 \quad (7)$$

$$\pi_P^{HR}(t) = (p-w)q - \frac{1}{2}t^2 \quad (8)$$

When the manufacturer resells green products in reselling platform supply chain with government subsidy, he determines the green technology level and unit wholesale price of green products. Then, the platform determines the data-driven marketing level and unit selling price of green products. The equilibrium decisions of the manufacturer and the platform can be obtained as shown in proposition 4 with the backward induction method.

Proposition 4. *The equilibrium decisions of the reselling platform supply chain with government subsidy are:* $m^{HR*} = \frac{(\alpha+s)\left(2-k^2\right)}{2(2-k^2)-\sigma^2}$, $w^{HR*} = \frac{\alpha+\left(2k^2-3+\omega^2\right)s}{2(2-k^2)-\sigma^2}$, $p^{HR*} = \frac{\left(3-k^2\right)\alpha+s\left(k^2+\omega^2-1\right)}{2(2-k^2)-\sigma^2}$, $q^{HR*} = \frac{\alpha+s}{2(2-k^2)-\sigma^2}$, $e^{HR*} = \frac{k(\alpha+s)}{2(2-k^2)-\sigma^2}$, $t^{HR*} = \frac{\omega(\alpha+s)}{2(2-k^2)-\sigma^2}$, $\pi_M^{HR*} = \frac{\left(2-k^2\right)(\alpha+s)^2}{2[2(2-k^2)-\sigma^2]^2}$, $\pi_P^{HR*} = \frac{(\alpha+s)^2}{2[2(2-k^2)-\sigma^2]}$.

Conclusion 5. *In order to make the unit selling price of green products and the smart platform's profit positive, government subsidy needs to be satisfied* $s < \frac{\alpha}{3-2k^2-\omega^2}$. *In other words, under the reselling strategy, government subsidy to the manufacturer should not be too high to ensure that smart platform is profitable. The same as in conclusion 3.*

Based on the equilibrium decisions of the manufacturer and the platform in proposition 4, we can further analyze the impacts of the parameters of government subsidy on all members decisions and profits. Please see Conclusion 6.

Conclusion 6. *The impact of government subsidy on the equilibrium decisions of reselling platform system with government subsidy are as follows:* $\frac{\partial w^{HR*}}{\partial s} < 0$, $\frac{\partial m^{HR*}}{\partial s} > 0$, $\frac{\partial p^{HR*}}{\partial s} < 0$, $\frac{\partial q^{HR*}}{\partial s} > 0$, $\frac{\partial e^{HR*}}{\partial s} > 0$, $\frac{\partial t^{HR*}}{\partial s} > 0$, $\frac{\partial \pi_M^{HR*}}{\partial s} > 0$, $\frac{\partial \pi_P^{HR*}}{\partial s} > 0$.

In the reselling platform supply chain with government subsidy, conclusion 6 shows that:

Government subsidy can motivate the manufacturer to improve the green technology level and reduce the unit wholesale price of green products. Therefore, the smart platform has more rising ranges of price, but to sell more green products and gain more profits, the smart platform should reduce the unit selling price of green products driven by the concept of small profits with quick turnover. At the same time, the smart platform should improve her data-driven marketing level to further increase the market demand of green products. On this basis, the increases of government subsidy and the manufacturer's income exceed the increase in green technology investment cost, so the manufacturer's profit increases. For the smart platform, the increase in its income is more than the increase in data-driven marketing cost, so the smart platform's profit also increases.

Theorem 3. *Comparing the equilibrium decisions of reselling platform supply chain with and without government subsidy, we can find that: (1)* $\pi_P^{HR*} > \pi_P^{NR*}$. *(2)* $\pi_M^{HR*} > \pi_M^{NR*}$. *(3)* $e^{HR*} > e^{NR*}$. *(4)* $t^{HR*} > t^{NR*}$. *(5)* $w^{HR*} < w^{NR*}$. *(6)* $q^{HR*} > q^{NR*}$. *(7) if* $\sigma > \sqrt{1-k^2}$, $p^{HR*} > p^{NR*}$, *and elseif* $\sigma < \sqrt{1-k^2}$, $p^{HR*} < p^{NR*}$.

Please see Appendix C for detailed proof process about Theorem 3.

In the reselling platform supply chain with or without government subsidy, we can find by combining conclusion 6 with theorem 3:

With government subsidy, it can be seen that the manufacturer reduces the unit wholesale price of green products while improving the green technology level. The smart platform should reduce the unit selling price of green products, but her raising range of price will expand. At the same time, the smart platform should improve her data-driven marketing level. This will make the positive utility of increasing market demand of green products greater than the negative utility of reducing its unit selling price. For all these reasons, the profits of the manufacturer and the smart platform are higher than they would be without subsidy. Therefore, compared with the system with government subsidy, the unit wholesale price of green products is lower than that in the system without government subsidy, and the green technology level of the manufacturer, the data-driven marketing level of the smart platform, the market demand of green products, and all members' profits are all higher than these in the system without government subsidy. However, if consumers are more sensitive to data analysis technology, the unit of product selling price in the system without government subsidy is higher than that in the system with government subsidy, the opposite is lower than the system with government subsidy.

5.3. The Service Commission Rate and Government Subsidy Analysis

We set $\alpha = 1$, $\eta = 0.2$, $s = 0.3$, $k = 0.3$, $\sigma = 0.4$ to analyze the impacts of the sensitivities of consumers to green product attribute and data analysis technology, and the service commission rate and government subsidy on the manufacturer's green technology level and all members' profits in Figure 3a,b.

1. In the platform supply chain without government subsidy, if consumers are not sensitive to the data-driven marketing technology (see Figure 3a), with the increase in the service commission rate, the manufacturer's green technology level and profit decreases under the agency selling strategy, while the smart platform's profit increases. If consumers are sensitive to data-driven marketing technology invested by the smart platform (see Figure 3b), with the increase in the service commission rate, the manufacturer's green technology level under the agency selling strategy decreases and his profit increases, while the smart platform's increases, which conforms to conclusion 1. If the service commission rate is low, the manufacturer chooses an agency selling strategy that can obtain more profit, but at this moment, the green technology level is not necessarily higher than that in the reselling system, therefore the smart platform should choose the reselling strategy. If the service commission rate is high (see Figure 3a,b), and the manufacturer chooses the reselling strategy and can obtain more profit, the green technology level under this strategy would also be higher, while the smart platform should choose the agency selling strategy, which conforms to theorem 1.
2. In the agency selling platform supply chain with government subsidy, with the increase in government subsidy, the green technology level and the manufacturer's profit increase, while the smart platform's profit increases first and then decrease, which is consistent with conclusions 4. If consumers are insensitive to data-driven marketing technology (see Figure 3a), the manufacturer's green technology level and profit are higher than those in the system without government subsidy, but the smart platform's profit is lower than that in the system without government subsidy. If consumers are sensitive to data-driven marketing technology (see Figure 3b), the manufacturer's green technology level and profit, and the smart platform's profit are higher than those in the system without government subsidy, in line with theorem 2.
3. In the reselling platform supply chain with government subsidy, with the increase in government subsidy, the green technology level increases, and the profits of the manufacturer and the smart platform increase, which is consistent with conclusions 6. The manufacturer's green technology level and profit, and the smart platform's profit are higher than those in the system without government subsidy, in line with theorem 3.
4. With or without government subsidy, if the service commission rate charged by the platform is low, the manufacturer chooses an agency selling strategy that can obtain more profits, but at this moment, the green technology level would not necessarily be higher than that in the reselling system, therefore the smart platform should choose the reselling strategy. If the service commission rate charged by the smart platform is higher, the manufacturer chooses the reselling strategy and can obtain high profits, and the green technology level under the reselling strategy is also higher than that in the agency selling system, while the smart platform chooses the agency selling strategy, the same as theorem 1. However, when the service commission rate charged by the smart platform falls into a certain range of threshold value, if government has no subsidy or less subsidy, the unit selling price that the manufacturer directly selling

in agency selling system will be too low, so the smart platform can benefit more from the service commission, she should choose agency selling strategy. Now, her selling strategy reaches an agreement with the manufacturer. However, the manufacturer's green technology level is not high. Along with the increase in government subsidy, and the manufacturer greatly reducing the unit selling price of green products, this will reduce the commission fee and profit earned by the smart platform under the agency selling strategy. When the government subsidy is larger than the threshold in conclusion 3, but fails to reach the threshold in conclusion 5, the smart platform's profit is negative, so both the smart platform and the manufacturer should turn to the reselling strategy. At this time, the manufacturer's green technology level is also high.

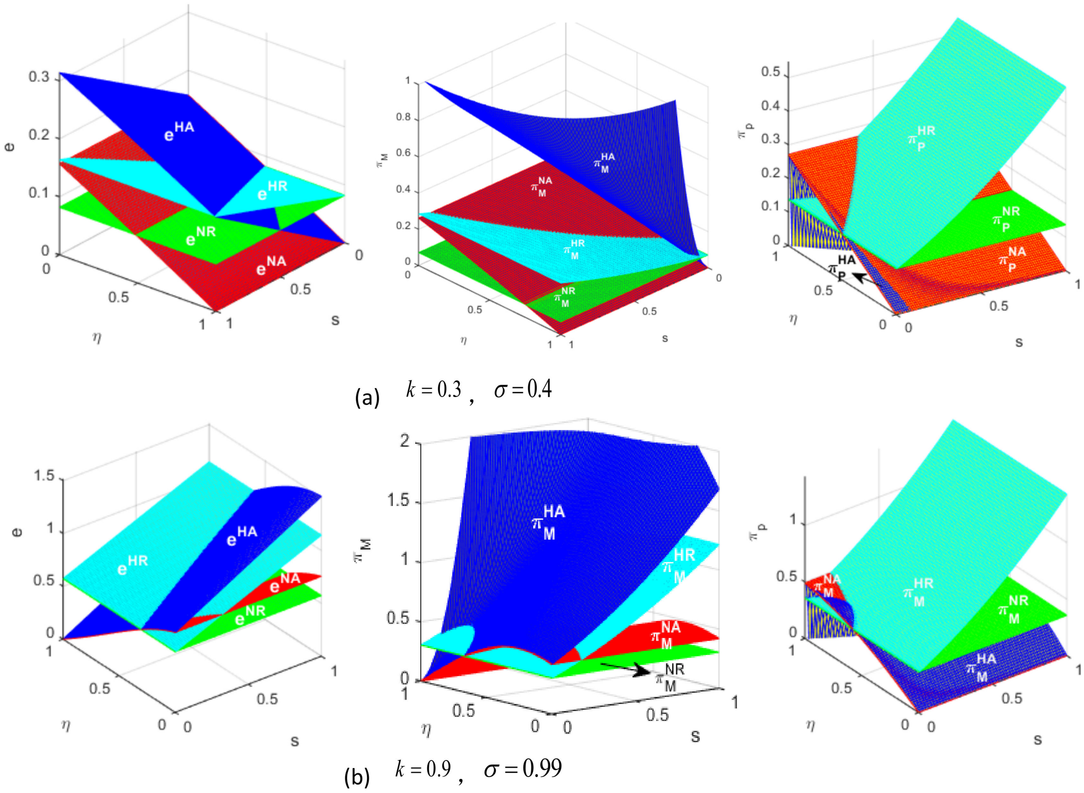

Figure 3. The impact of service commission rate and government subsidy on green technology level and all members' profits.

6. Conclusions

The rapid development of economy makes environmental problems more and more serious. Global climate deterioration has become an important issue of concern to the international community. To reduce carbon emissions, President Xi Jinping announced at the Climate Ambition Summit sponsored by the United Nations and relevant countries that China will adopt more robust policies and measures, including subsidies for manufacturers based on the number of green products they produce and sell. In this case, companies need to consider the carbon emissions of their operations. However, the current research mainly focuses on traditional and sustainable supply chains. With the development of the smart platform economy, it can give full play to its data advantages to reduce and eliminate carbon emissions in the operation process of the industrial chain. Therefore, it is of theoretical value and practical significance to study how the government guides manufacturers to participate in the operation of smart platform supply chain, and to invest in green technologies to improve ecological benefits while taking into account economic benefits. This paper aims to explore how the manufacturer executes green technology in a platform system and chooses selling strategy, and how the government can guide the manufacturer invest in green technology to improve ecological benefits while giving consideration to economic benefits. Therefore, the aim is to have a smart platform supply chain composed of a manufacturer and a smart platform. The manufacturer invests in green technology to produces green products, and the smart platform invests in data analysis technology to promote the sales of the green products. The manufacturer is considered to choose to sell products with an agency selling or reselling strategy through the smart platform, respectively, and four game models of a smart supply chain with or without government subsidy are constructed, respectively. Through comparative study, this paper discusses the manufacturer's choice of selling strategy and the impact of government subsidy on all members' choice of selling strategy. Combined with numerical example analysis, the following conclusions are obtained:

1. In the smart platform supply chain with agency selling or reselling strategy, when the potential market demand of green products, and the sensitivities of consumers to green product attributes and data analysis increases, the manufacturer's green technology level, the smart platform's data-driven marketing level, the market demand and selling price of green products increases, which are beneficial to the ecological benefit of the smart platform supply chain and all members' profits.
2. In the agency selling platform supply chain with government subsidy, the manufacturer's green R&D activities can be effectively motivated, he is willing to improve the green technology investment level while reducing the unit selling price of green products, which is conducive to both encouraging consumers to buy more green products and benefiting the manufacturer to obtain more profit. However, along with the government subsidy increases, the platform's profit increases first. When the government subsidy increases to a certain degree that motivates the manufacturer to reduce the unit selling price of the green products more, the platform's profit will be damaged for lower service commission income, which is bad for her participation in agency selling platform supply chain. Therefore, the government should set appropriate subsidies for the manufacturer's R&D activities in agency selling system. In the reselling platform supply chain with government subsidy, the manufacturer's green R&D activities can be effectively motivated, and he is willing to improve the green technology investment level while reducing the unit wholesale price of green products. On this basis, the smart platform is willing to improve the data-driven marketing level while reducing the unit selling price of green products. These behaviors of the manufacturer and the smart platform can make them more profit by increasing consumer quantities. Thus, the more government subsidies, the more conducive to better achieve win-win economic and ecological benefits in reselling platform supply chain. Therefore, in order to ensure that the platform makes better use of data driven marketing technology to promote products, the government subsidy should be moderated in the agency selling platform supply chain, e.g., Amazon sellers, while being increased in the reselling platform supply chain, e.g., JD.COM sellers.
3. The service commission rate charged by the smart platform and government subsidy plays a major role in the choice of green product selling strategy. If the service commission rate is low, the manufacturer should choose an agency selling strategy, but now the manufacturer's green technology level is not necessarily the highest. With the improvement of the service commission rate, the manufacturer should choose a reselling strategy, and the green technology level is higher than it in the agency selling system. However, when the smart platform charge service commission rate in a certain range, if the government subsidy is less, the manufacturer and the smart platform should also choose agency selling strategy, but the green technology level is not high. When the government subsidy increases to a certain extent, the manufacturer and the platform should also choose a reselling strategy, and the green technology level is high. It also means that all members agree on a selling strategy, and the economic and ecological benefits are well realized.

Some limitations exist in our paper, the following aspects can be expanded. We only considered a platform supply chain composed of one manufacturer and one platform. However, there are many competing members in each tier of the supply chain, so we should research the decision making and sales channel choice in the platform supply chain with two or more competing manufacturers and platforms. At the same time, we can explore the advantages of data analysis of smart platforms to help the manufacturer effectively lower the investment costs of green technology. Finally, we should discuss government subsidy on platforms' green promotion activities or consumers' green consumption activities, and further analyze which subsidies policy can achieve win-win economic, ecological, and social benefits. We also should discuss the impacts of more government green policies on the operation management of smart platform supply chain, such as carbon trading and carbon tax.

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Appendix A

The proof of the equilibrium decisions of the platform supply chain under the agency selling strategy without government subsidy in proposition 1.

Through the backward induction, we take the derivative of the manufacturer's profit function with respect to p, e as follows, respectively:

$$\frac{\partial \pi_M^{NA}}{\partial p} = (1-\eta)(\alpha + ke + \sigma t) - 2(1-\eta)p \tag{A1}$$

$$\frac{\partial \pi_M^{NA}}{\partial p} = (1-\eta)(\alpha + ke + \sigma t) - 2(1-\eta)p \tag{A2}$$

Further obtained: $\frac{\partial^2 \pi_M^{NA}}{\partial p^2} = -2(1-\eta)$, $\frac{\partial^2 \pi_M^{NA}}{\partial e^2} = -1$, $\frac{\partial^2 \pi_M^{NA}}{\partial e \partial p} = k(1-\eta)$, and the Hessian matrix $H(p,e) = \begin{bmatrix} -2(1-\eta) & k(1-\eta) \\ k(1-\eta) & -1 \end{bmatrix}$. It is easy to find that the Hessian matrix is negative-definite, i.e., $-2(1-\eta) < 0, 2 - k^2(1-\eta) > 0$. So, the manufacturer's profits are strictly concave with respect to p, e.

Let Equations (A1) and (A2) be 0, we can get the manufacturer's response decisions about the platform's data-driven marketing level t:

$$p(t) = \frac{(1-\eta)(\alpha + \sigma t)}{-k^2(1-\eta)^2 + 2(1-\eta)} \tag{A3}$$

$$e(t) = \frac{k(1-\eta)(\alpha + \sigma t)}{2 - k^2(1-\eta)} \tag{A4}$$

By substituting the $p(t)$, $e(t)$ into the profit function of the smart platform and taking the derivative with respect to t as follows:

$$\frac{\partial \pi_P^{NA}}{\partial t} = 2\eta\omega \frac{\alpha + \sigma t}{\left[2 - k^2(1-\eta)\right]^2} - t \tag{A5}$$

Further:

$$\frac{\partial^2 \pi_P}{\partial t^2} = \frac{2\eta\sigma^2 - \left[2 - k^2(1-\eta)\right]^2}{\left[2 - k^2(1-\eta)\right]^2} \tag{A6}$$

If and only if $\sigma < \frac{2-k^2(1-\eta)}{\sqrt{2\eta}}$, the profit function of the smart platform is concave about t. The impact of data analysis technology on the market demand is limited. That is, it cannot fully mine the demand information of consumers. For example, although Taobao can collect user data in the background and recommend products for users through the "guess what you like" function, the products cannot fully meet the needs of users.

Let Equation (A5) be 0, the data-driven marketing level of the smart platform is: $t^{NA*} = \frac{2\alpha\eta\sigma}{\left[2-k^2(1-\eta)\right]^2 - 2\eta\sigma^2}$.

Substituting t^{NA*} into $p(t)$,$e(t)$, and the market demand and profit functions of the manufacturer and the smart platform, Proposition 1 can be obtained.

Proposition 2, 3, 4 can be obtained by the similar proof process, so we omit.

Appendix B

The proof of the impacts of the potential market demand of green products, the sensitivity coefficients of consumers to green product attributes and data analysis technology, and the service commission rate on the equilibrium decisions of agency selling platform supply chain in conclusion 1.

$$\frac{\partial e^{NA}}{\partial k} = \alpha(1-\eta)\frac{\left[2 + k^2(1-\eta)\right]\left[2 - k^2(1-\eta)\right]^2 - \left[2 - 3k^2(1-\eta)\right]2\eta\sigma^2}{\left[(2 - k^2(1-\eta))^2 - 2\eta\sigma^2\right]^2} \tag{A7}$$

Because $2 + k^2(1-\eta) > 2 - 3k^2(1-\eta)$ and $\left[2 - k^2(1-\eta)\right]^2 > 2\eta\sigma^2$, so $\left[2 + k^2(1-\eta)\right]\left[2 - k^2(1-\eta)\right]^2 - 2\eta\sigma^2\left[2 - 3k^2(1-\eta)\right] > 0$, therefore $\partial e^{NA}/\partial k > 0$.

$$\frac{\partial \pi_M^{NA*}}{\partial \eta} = \frac{\alpha^2\left[2-k^2(1-\eta)\right]^2\left\{\left[2-k^2(1-\eta)\right]^2 - 2\eta\sigma^2\right\}\left\{2\sigma^2\left[2-\eta-k^2\left(1-\eta^2\right)\right] - \left(2-k^2(1-\eta)\right)^2\right\}}{\left\{\left[2-k^2(1-\eta)\right]^2 - 2\eta\sigma^2\right\}^4} \tag{A8}$$

When $2\sigma^2\left[2-\eta-k^2\left(1-\eta^2\right)\right] - \left[2-k^2(1-\eta)\right]^2 > 0$, $\frac{\partial \pi_M^{NA*}}{\partial \eta} > 0$; when $2\sigma^2\left[2-\eta-k^2\left(1-\eta^2\right)\right] - \left[2-k^2(1-\eta)\right]^2 < 0$, $\frac{\partial \pi_M^{NA*}}{\partial \eta} < 0$.

Conclusion 2, 4, 6 can be obtained by the similar proof process, so we omit.

Appendix C

1. The Comparison of the equilibrium decisions of agency selling and reselling platform supply chain in Theorem 1.

   (1) Because $2\eta\sigma^2 - \left[2-k^2(1-\eta)\right]^2 < 0$, therefore, it can be obtained $\pi_P^{\mathrm{NA}*} - \pi_P^{NR*} = \alpha^2\frac{4\eta\left(2-k^2\right) - 4 - k^4(1-\eta)^2 + 4k^2(1-\eta)}{2\left[2\left(2-k^2\right)-\sigma^2\right]\left\{\left[2-k^2(1-\eta)\right]^2 - 2\eta\sigma^2\right\}}$, so when $4\eta\left(2-k^2\right) - \left[2-k^2(1-\eta)\right]^2 > 0$, $\pi_P^{\mathrm{NA}*} > \pi_P^{NR*}$; when $4\eta\left(2-k^2\right) - \left[2-k^2(1-\eta)\right]^2 < 0$, $\pi_P^{\mathrm{NA}*} < \pi_P^{NR*}$.

(2) Because $\pi_M^{NA*} - \pi_M^{NR*} = \alpha^2 \frac{(1-\eta)\left[2-k^2(1-\eta)\right]^3\left[2\left(2-k^2\right)-\sigma^2\right]^2-\left(2-k^2\right)\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}^2}{2\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}^2\left[2\left(2-k^2\right)-\sigma^2\right]^2}$, when $(1-\eta)\left[2-k^2(1-\eta)\right]^3\left[2\left(2-k^2\right)-\sigma^2\right]^2 - \left(2-k^2\right)\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}^2 < 0$, $\pi_M^{NA*} < \pi_M^{NR*}$; when $(1-\eta)\left[2-k^2(1-\eta)\right]^3\left[2\left(2-k^2\right)-\sigma^2\right]^2 - \left(2-k^2\right)\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}^2 > 0$, $\pi_M^{NA*} > \pi_M^{NR*}$.

(3) Because $e^{NA*} - e^{NR*} = \alpha k \frac{\left[2-4\eta-(1-\eta)k^2\right]\left[2-k^2(1-\eta)\right]-\left[2-4\eta-k^2(1-\eta)^2\right]\sigma^2}{\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}\left[2\left(2-k^2\right)-\sigma^2\right]}$, when $\left[2-4\eta-(1-\eta)k^2\right]\left[2-k^2(1-\eta)\right] - \left[2-4\eta-k^2(1-\eta)^2\right]\sigma^2 > 0$, find the solution of quadratic inequality of one variable for η that is: $\eta_2 = \frac{\left(k^4-4k^2+\sigma^2k^2-2\sigma^2+4\right)-\sqrt{\left(4-2\sigma^2\right)\left(k^4-4k^2+\sigma^2k^2-2\sigma^2+4\right)}}{\left(k^2+\sigma^2\right)k^2-4k^2}$, when $\eta < \eta_2$, $e^{NA*} > e^{NR*}$; when $\eta > \eta_2$, $e^{NA*} < e^{NR*}$.

(4) $q^{NA*} - q^{NR*} = \alpha \frac{\left[2-k^2(1-\eta)\right]\left[2-\sigma^2-k^2(1+\eta)\right]+2\eta\sigma^2}{\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}\left[2\left(2-k^2\right)-\sigma^2\right]} > 0$.

(5) Because $t^{NA*} - t^{NR*} = \alpha\sigma \frac{4\eta\left(2-k^2\right)-\left[2-k^2(1-\eta)\right]^2}{\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}\left[2\left(2-k^2\right)-\sigma^2\right]}$, when $4\eta\left(2-k^2\right) - \left[2-k^2(1-\eta)\right]^2 > 0$, $\eta > \eta_1 = \left(2-k^2\right)\frac{\left(2-k^2\right)\pm 2\sqrt{\left(1-k^2\right)}}{k^4}$. So, when $\eta < \eta_1$, $t^{NA*} < t^{NR*}$; when $\eta > \eta_1$, $t^{NA*} > t^{NR*}$.

(6) $p^{NA*} - p^{NR*} = \frac{\alpha\left[2-k^2(1-\eta)\right]}{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2} - \frac{\alpha\left(3-k^2\right)}{2\left(2-k^2\right)-\sigma^2}$. Because $2-k^2(1-\eta) < 3-k^2$ and $\left[2-k^2(1-\eta)\right]^2 - 2\eta\sigma^2 > 2\left(2-k^2\right) - \sigma^2$, so $p^{NA*} - p^{NR*} < 0$.

2. The comparison of the equilibrium decisions of agency selling platform supply chain with and without government subsidy in Theorem 2.

Because $\pi_P^{HA*} - \pi_P^{NA*} = \eta \frac{2\eta k^2\left[(\eta-2)s\alpha-s^2\right]+2s\left[(\alpha+s)k^2-s\right]+\eta s^2\sigma^2}{2(1-\eta)^2\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}}$. When $2\eta k^2\left[(\eta-2)s\alpha-s^2\right] + 2s\left[(\alpha+s)k^2-s\right] + \eta s^2\sigma^2 > 0$, therefore, it can be obtained $\sigma > \sqrt{\frac{2\left(1-k^2(1-\eta)\right)s^2-2\alpha(1-\eta)^2\left(sk^2+\alpha(1-\eta)\right)}{\eta s^2}}$, namely $\pi_P^{HA*} - \pi_P^{NA*} > 0$. Similarly, when $\sigma < \sqrt{\frac{2\left(1-k^2(1-\eta)\right)s^2-2\alpha(1-\eta)^2\left(sk^2+\alpha(1-\eta)\right)}{\eta s^2}}$, $\pi_P^{HA*} - \pi_P^{NA*} < 0$.
$t^{HA*} - t^{NA*} = \frac{\eta\sigma k^2 s}{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2} > 0$, $e^{HA*} - e^{NA*} = ks \frac{\left[2-k^2(1-\eta)\right]-\eta\sigma^2}{\left[\left(2-k^2(1-\eta)\right)^2-2\eta\sigma^2\right]} > 0$,
$\pi_M^{HA*} - \pi_M^{NA*} = \frac{\left[2-(1-\eta)k^2\right]\left[sk^2(1-\eta)+s\eta\sigma^2-2s\right]\left\{\left[(1-\eta)k^2+\eta\sigma^2-2\right]s-2\alpha(1-\eta)\left[2-k^2(1-\eta)\right]\right\}}{2(1-\eta)\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}^2} > 0$,
$p^{HA*} - p^{NA*} = \frac{\left[2-k^2(1-\eta)\right]^2\left[(1-\eta)k^2s-s-\alpha\eta\right]+\eta\sigma^2s\left[k(1-\eta)(1-2k)+2\right]}{(1-\eta)\left[2-k^2(1-\eta)\right]\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}} < 0$,
$q^{HA*} - q^{NA*} = s\frac{\left[2-k^2(1-\eta)\right]^2\left[k^2(1-\eta)-k(1-\eta)+1\right]+\eta\sigma^2\left[2k(1-\eta)-k^2(1-\eta)-2\right]}{(1-\eta)\left[2-k^2(1-\eta)\right]\left\{\left[2-k^2(1-\eta)\right]^2-2\eta\sigma^2\right\}} > 0$.

3. The comparison of the equilibrium decisions of reselling platform supply chain with and without government subsidy in Theorem 3.

$\pi_P^{HR*} - \pi_P^{NR*} = \frac{(\alpha+s)^2}{2\left[2\left(2-k^2\right)-\sigma^2\right]} - \frac{\alpha^2}{2\left[2\left(2-k^2\right)-\sigma^2\right]} > 0$; $\pi_M^{HR*} - \pi_M^{NR*} = \frac{\left(2-k^2\right)\left[(\alpha+s)^2-\alpha^2\right]}{2\left[2\left(2-k^2\right)-\sigma^2\right]^2} > 0$; $e^{HR*} - e^{NR*} = \frac{ks}{2\left(2-k^2\right)-\sigma^2} > 0$; $t^{HR*} - t^{NR*} = \frac{\sigma(\alpha+s)}{2\left(2-k^2\right)-\sigma^2} - \frac{\alpha\sigma}{4-\sigma^2-2k^2} > 0$; $w^{HR*} - w^{NR*} = s\frac{\left(2k^2+\sigma^2-3\right)}{2\left(2-k^2\right)-\sigma^2} < 0$; $q^{HR*} - q^{NR*} = \frac{\alpha+s}{4-\sigma^2-2k^2} - \frac{\alpha}{4-\sigma^2-2k^2} > 0$; $p^{HR*} - p^{NR*} = \frac{\left(k^2-1+\sigma^2\right)s}{2\left(2-k^2\right)-\sigma^2}$; When $k^2-1+\sigma^2 > 0$, $p^{HR*} - p^{NR*} > 0$; when $k^2-1+\sigma^2 < 0$, $p^{HR*} - p^{NR*} < 0$.

References

1. Wright, J.; Hagiu, A. Marketplace or reseller? *Manag. Sci.* **2015**, *61*, 184–203.
2. Braverman, S. Global review of data-driven marketing and advertising. *J. Direct Data Digit. Mark. Pract.* **2015**, *16*, 181–183. [CrossRef]
3. Cohen, M.C. Big data and service operations. *Prod. Oper. Manag.* **2018**, *27*, 1709–1723. [CrossRef]
4. Ghoshal, A.; Kumar, S.; Mookerjee, V. Dilemma of data sharing alliance: When do competing personalizing and non-personalizing firms share data. *Prod. Oper. Manag.* **2020**, *29*, 1918–1936. [CrossRef]
5. Husted, B.W.; De, S.J. The impact of sustainability governance, country stakeholder orientation, and country risk on environmental, social, and governance performance. *J. Clean. Prod.* **2016**, *155 Pt 2*, 93–102. [CrossRef]
6. Wang, Z.; Sarkis, J. Corporate social responsibility governance, outcomes, and financial performance. *J. Clean. Prod.* **2017**, *162*, 1607–1616. [CrossRef]
7. Yang, Q.; Du, Q.; Razzaq, A. How volatility in green financing, clean energy, and green economic practices derive sustainable performance through ESG indicators? A sectoral study of G7 countries. *Resour. Policy* **2022**, *75*, 102526. [CrossRef]
8. Tan, Y.; Zhu, Z. The effect of ESG rating events on corporate green innovation in China: The mediating role of financial constraints and managers' environmental awareness. *Technol. Soc.* **2022**, *68*, 101906. [CrossRef]
9. Zhu, Q.H.; Sarkis, J. Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. *J. Oper. Manag.* **2004**, *22*, 265–289. [CrossRef]
10. Chiou, T.Y.; Chan, H.K. The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. *Transp. Res. Part E Logist. Transp. Rev.* **2011**, *47*, 822–836. [CrossRef]
11. Handfield, R.B.; Walton, S. Green supply chain: Best practices from the furniture industry. In Proceedings of the Proceedings Annual Meeting of the Decision Sciences Institute, Orlando, FL, USA, 24–26 November 1996; pp. 1295–1297.
12. Nagel, M.H. Environmental supply-chain management versus green procurement in the scope of a business and leadership perspective. In Proceedings of the IEEE International Symposium on Electronics and the Environment, San Francisco, CA, USA, 10 May 2000; pp. 219–224.
13. Hall, J. Environmental supply chain dynamics. *J. Clean. Prod.* **2000**, *8*, 455–471. [CrossRef]
14. Zsidisin, G.A.; Siferd, S.P. Environmental purchasing: A framework for theory development. *Eur. J. Purch. Supply Manag.* **2001**, *7*, 61–73. [CrossRef]
15. Tachizawa, E.M.; Gimenez, C. Green supply chain management approaches: Drivers and performance implications. *Int. J. Oper. Prod. Manag.* **2015**, *35*, 1546–1566. [CrossRef]
16. Rahmani, K.; Yavari, M. Pricing policies for a dual-channel green supply chain under demand disruptions. *Comput. Ind. Eng.* **2018**, *127*, 493–510. [CrossRef]
17. Nekmahmud, M.; Rahman, S.; Sobhani, F.A.; Olejniczak, S.K.; Fekete, F.M. A systematic literature review on development of green supply chain management. *Pol. J. Manag. Stud.* **2020**, *22*, 351–370. [CrossRef]
18. Hariharasudan, A.; Kot, S.; Sangeetha, J. The decades of research on SCM and its advancements: Comprehensive framework. *Acta Logist.* **2021**, *8*, 455–477. [CrossRef]
19. Astawa, I.K.; Pirzada, K.; Budarma, I.K.; Widhari, C.I.S.; Suardani, A.A.P. The effect of green supply chain management practices on the competitive advantages and organizational performance. *Pol. J. Manag. Stud.* **2021**, *24*, 45–60. [CrossRef]
20. Kot, S.; Ul Haque, A.; Baloch, A. Supply chain management in SMEs: Global perspective. *Montenegrin J. Econ.* **2020**, *16*, 87–104. [CrossRef]
21. Liu, Z.; Lang, L.; Hu, B. Emission reduction decision of agricultural supply chain considering carbon tax and investment cooperation. *J. Clean. Prod.* **2021**, *294*, 126305. [CrossRef]
22. Ma, S.; He, Y.; Gu, R. Sustainable supply chain management considering technology investments and government intervention. *Transp. Res. Part E Logist. Transp. Rev.* **2021**, *149*, 102290. [CrossRef]
23. Zhu, W.; He, Y.J. Green product design in supply chains under competition. *Eur. J. Oper. Res.* **2017**, *258*, 165–180. [CrossRef]
24. Hong, Z.F.; Wang, H.; Gong, Y.M. Green product design considering functional-product reference. *Int. J. Prod. Econ.* **2019**, *210*, 155–168. [CrossRef]
25. Drake, D.F. Carbon tariffs: Effects in settings with technology choice and foreign production cost advantage. *Manuf. Serv. Oper. Manag.* **2018**, *20*, 667–686. [CrossRef]
26. Wu, H.Q.; Hu, S.M. The impact of synergy effect between government subsidies and slack resources on green technology innovation. *J. Clean. Prod.* **2020**, *274*, 122682. [CrossRef]
27. Li, Y. Research on supply chain CSR management based on differential game. *J. Clean. Prod.* **2020**, *268*, 122171. [CrossRef]
28. Yang, R.; Tang, W.S. Technology improvement strategy for green products under competition: The role of government subsidy. *Eur. J. Oper. Res.* **2021**, *289*, 553–568. [CrossRef]
29. Gao, J.; Xiao, Z.; Wei, H. Dual-channel green supply chain management with eco-label policy: A perspective of two types of green products. *Comput. Ind. Eng.* **2020**, *146*, 106613. [CrossRef]
30. Xue, J.; Gong, R.F. A green supply-chain decision model for energy-saving products that accounts for government subsidies. *Sustainability* **2019**, *11*, 2209. [CrossRef]
31. Li, C.F.; Liu, Q.L. Optimal innovation investment: The role of subsidy schemes and supply chain channel power structure. *Comput. Ind. Eng.* **2021**, *157*, 107291. [CrossRef]

32. Chen, J.Y.; Stanko, D. The impact of government subsidy on supply chains' sustainability innovation. *Omega* **2019**, *86*, 42–58. [CrossRef]
33. Bi, G.; Jin, M.; Ling, L. Environmental subsidy and the choice of green technology in the presence of green consumers. *Ann. Oper. Res.* **2017**, *255*, 547–568. [CrossRef]
34. Cohen, M.C.; Lobel, R.; Perakis, G. The impact of demand uncertainty on consumer subsidies for green technology adoption. *Manag. Sci.* **2016**, *62*, 1235–1258. [CrossRef]
35. Jung, S.H.; Feng, T. Government subsidies for green technology development under uncertainty. *Eur. J. Oper. Res.* **2020**, *286*, 726–739. [CrossRef]
36. Yang, D.Y.; Xiao, T.J. Pricing and green level decisions of a green supply chain with governmental interventions under fuzzy uncertainties. *J. Clean. Prod.* **2017**, *149*, 1174–1187. [CrossRef]
37. Fu, J.F.; Chen, X.F. Subidizing strategies in a sustainable supply chain. *J. Oper. Res. Soc.* **2018**, *69*, 283–295. [CrossRef]
38. Yu, J.J.; Tang, C.S.; Shen, Z.J.M. Improving consumer welfare and manufacturer profit via government subsidy programs: Subsidizing consumers or manufacturers? *Manuf. Serv. Oper. Manag.* **2018**, *20*, 752–766. [CrossRef]
39. Bian, J.S.; Zhang, G.Q. Manufacturer vs. consumer subsidy with green technology investment and environmental concern. *Eur. J. Oper. Res.* **2020**, *287*, 832–843. [CrossRef]
40. Lu, Q.; Shi, V.; Huang, J. Who benefit from agency model: A strategic analysis of pricing models in distribution channels of physical books and e-books. *Eur. J. Oper. Res.* **2017**, *264*, 25–29. [CrossRef]
41. Zhang, J.; Cao, Q.; He, X. Contract and product quality in platform selling. *Eur. J. Oper. Res.* **2018**, *272*, 928–944. [CrossRef]
42. Du, S.F.; Wang, L.; Hu, L. Platform-led green advertising: Promote the best or promote by performance. *Transp. Res. Part E Logist. Transp. Rev.* **2019**, *128*, 115–131. [CrossRef]
43. Li, X. Reducing channel costs by investing in smart supply chain technologies. *Transp. Res. Part E Logist. Transp. Rev.* **2020**, *137*, 101927. [CrossRef]
44. Liu, W.H.; Yan, X.Y.; Li, X. The impacts of market size and data-driven marketing on the sales mode selection in an Internet platform based supply chain. *Transp. Res. Part E Logist. Transp. Rev.* **2020**, *136*, 101914. [CrossRef]
45. Wan, X.L.; Qie, X.Q. Poverty alleviation ecosystem evolutionary game on smart supply chain platform under the government financial platform incentive mechanism. *J. Comput. Appl. Math.* **2020**, *372*, 112595. [CrossRef]
46. Liu, W.; Long, S.; Liang, Y. The influence of leadership and smart level on the strategy choice of the smart logistics platform: A perspective of collaborative innovation participation. *Ann. Oper. Res.* **2021**. [CrossRef]
47. Liu, W.; Wang, S.; Wang, J. Evaluation method of path selection for smart supply chain innovation. *Ann. Oper. Res.* **2021**. [CrossRef]
48. Xiao, D.; Kuang, X.; Chen, K. E-commerce supply chain decisions under platform digital empowerment-induced demand. *Comput. Ind. Eng.* **2020**, *150*, 106876. [CrossRef]
49. Hao, L.; Fan, M. An analysis of pricing models in the electronic book market. *MIS Quart.* **2014**, *38*, 1017–1032. [CrossRef]
50. Young, K.; Chen, J.; Raghunathan, S. Online product reviews: Implications for retailers and competing manufacturers. *Inf. Syst. Res.* **2014**, *25*, 93–110.
51. Abhishek, V.; Jerath, K.; Zhang, Z.J. Agency selling or reselling? channel structures in electronic retailing. *Manag. Sci.* **2016**, *62*, 2259–2280. [CrossRef]
52. Tan, Y.; Carrillo, J.E.; Cheng, H.K. The agency model for digital goods. *Decis. Sci.* **2016**, *47*, 628–660. [CrossRef]
53. Tan, Y.L.; Carrillo, J.E. Strategic analysis of the agency model for digital goods. *Prod. Oper. Manag.* **2017**, *26*, 724–741. [CrossRef]
54. Tian, L.; Vakharia, A.J.; Tan, Y.L. Marketplace, reseller, or hybrid: Strategic analysis of an emerging e-commerce model. *Prod. Oper. Manag.* **2018**, *27*, 1595–1610. [CrossRef]
55. Zhang, S.; Zhang, J. Agency selling or reselling: E-tailer information sharing with supplier offline entry. *Eur. J. Oper. Res.* **2020**, *280*, 134–151. [CrossRef]
56. Chen, P.P.; Zhao, R.Q.; Yan, Y.C. Promotional pricing and online business model choice in the presence of retail competition. *Omega* **2020**, *94*, 102085. [CrossRef]
57. Tan, Y.L.; Carrillo, J. The agency model for digital goods: Strategic analysis of dual channels in electronic publishing industry. In Proceedings of the PICMET '14 Conference: Portland International Center for Management of Engineering and Technology; Infrastructure and Service Integration, Kanazawa, Japan, 27–31 July 2014; pp. 646–657.
58. Geng, X.J.; Tan, Y.L. How add-on pricing interacts with distribution contracts. *Prod. Oper. Manag.* **2018**, *27*, 605–623. [CrossRef]
59. Wei, J.; Lu, J.; Zhao, J. Interactions of competing manufacturers' leader-follower relationship and sales format on online platforms. *Eur. J. Oper. Res.* **2019**, *280*, 37–48. [CrossRef]
60. Xu, Y.M.; Zhang, P. Decision-making in dual-channel green supply chain considering market structure. *J. Serv. Sci. Manag.* **2018**, *11*, 116–141. [CrossRef]
61. Yang, D.; Xiao, T.; Huang, J. Dual-channel structure choice of an environmental responsibility supply chain with green investment. *J. Clean. Prod.* **2019**, *210*, 134–145. [CrossRef]