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The process optimization method of the optimal online sales model of information product demand concerning the spillover effect

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Abstract

Purpose – This paper examines the process optimization method of the online sales model of information product demand concerning the spillover effect. It illustrates the spillover effect (SE) of online product demand compared with traditional market demand. Also, optimized the SE for the ethical and ordinary consumer.

Design/methodology/approach – This article primarily focused on two types of models for online marketing: one is wholesales, and another is the agency. Firstly, the wholesale and agency models without SE and the wholesale and agency models with SE are constructed, respectively, to realize the SE in different sales models. Secondly, online channel participants' optimal price, demand and profit under variant conditions are compared and analyzed. Finally, efficient supply chain theory is optimized for the decision-making of online marketing consumers using an equation-based comparative analysis method.

Findings – The study found that when SEs are not considered, stronger piracy regulation makes online channel participants more beneficial. When the positive SE is strong, it is detrimental to manufacturers. When SEs are not considered, online channel participants only reach Pareto in agency mode. Pareto optimality can be achieved in wholesale and agency modes when SEs are considered.

Originality/value – The research has practical implications for an effective supply chain model for online marketing. This is the first algorithm-based comparative study concerning theoretical spillover effect analysis in supply chain management.

Keywords Products information, Spillover effect, Effective supply chain, Digital piracy, Online business model

Paper type Research paper

1. Introduction

The spillover effect represents the change in the sector's performance wherein policy change or the change in the performance of other sectors to which that sector is linked is exercised

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(Baber, 2020). The effects may be horizontal (i.e. intra-industry) or vertical (i.e. inter-industry) spillovers (Wang and Wu, 2016). Horizontal spillovers refer to knowledge spillovers (transfer of knowledge) within an industry because of multinational industry presence (He *et al.*, 2019). Vertical spillovers occur between online and offline marketing. The vertical spillovers may occur through backward linkage (from buyers to suppliers) and forward linkage (from suppliers to buyers). Backward linkages create technology spillovers through various channels; firstly, online market may transfer technology directly to their online sales market by training or providing technical assistance in order to improve the quality of the supplier's products. Secondly, close linkages between the online channel and their local suppliers may persuade workers in the online sales market to turn to local suppliers, thereby diffusing technology and knowledge from the online sales market to domestic firms. Thirdly, higher standards for product quality and on-time delivery set by the online sales market may encourage local suppliers to improve their product quality through better management, improved technology or process and efficient utilization of resources (Havranek and Irsova, 2011).

Concerning the popularization and development of Internet technology, information products from traditional channels, such as books, music and movies, have been digitized and sold through online channels (Waldfogel, 2017). At present, there are mainly two sales modes in online media: wholesale mode and agency mode (Liu *et al.*, 2020). Under the wholesale model, online retailers obtain products from manufacturers at wholesale prices and then sell the products to consumers at retail prices. For example, digital music copyright owners and Apple's iTunes platform adopt a wholesale model to sell digital music. Under the model, manufacturers sell products directly through online retailers, and online retailers charge a commission proportional to the transaction amount. For example, book publishers and Amazon's e-commerce platform adopt an agency model to sell e-books. The essential difference between the two models lies in the ownership of the decision-making power of retail product prices. In the wholesale model, the online retailer determines the retail price. On the other hand, the manufacturer determines the retail price in the agency model.

Due to the characteristics of low dissemination cost, easy copying and zero marginal cost of digital information products, piracy becomes easier (Peitz and Waelbroeck, 2003, 2006). The total demand for digital products in online channels (including genuine and pirated markets) has an SE on traditional channel demand (Chen *et al.*, 2023; Danaher *et al.*, 2010). When the SE is positive, online channel demand can expand offline demand. For example, the SE of music products is positive. Suppose a singer's digital music downloads are larger (including paid downloads and free downloads of pirated versions), and the singer's popularity increases. And the demand for various offline music derivative products is excellent. When the SE is negative, the market in online channels leads to a decrease in order in the traditional market. For example, the SE of film products is harmful. As more and more users watch online movies on the internet, moviegoers in movie theaters will decrease. Then, in the presence of digital piracy, how manufacturers choose effective sales models according to different SEs becomes particularly important.

Based on this, the relevant literature is introduced from the following three. First is the online marketing sales model. Hagiu *et al.* explored the influence of product diversity endogenous network effect on platform pricing structure from the perspective of the bilateral market. They pointed out that consumers' product diversity preferences will affect the platform pricing structure (Sanchez-Cartas and León, 2021). Hagiu *et al.* pointed out that whether an e-commerce platform chooses to become a third-party intermediary or self-operated as an online distributor depends on the amount of information on product marketing (Roson, 2005). Chen *et al.* studied the influence of consumer loyalty on online channel sales strategies (Chen *et al.*, 2013). When consumer loyalty is high enough, it is more

beneficial for online retailers to adopt an agency model. Otherwise, it is more advantageous to adopt a wholesale model. The relationship between the product bundling strategy of tourism product providers and the online channel sales model found that providers tend to adopt bundling core products and additional products (Garrod and Fyall, 2017). Following the agency model, it is more beneficial for the provider to sell different products separately (He, 2012). When the quality dimension is dominant, if the accuracy of the third-party information is high enough, online retailers can benefit from the third-party information by adopting a wholesale strategy. Otherwise, it is better to adopt an agency strategy. Although the above literature studies the sales model of online channels, it does not consider the impact of SEs on the sales model of the online market. Based on the perspective of electronic retailers, Abhishek *et al.* acknowledged that when the SE is negative, online retailers tend to choose the agency model. Otherwise, it is better to select the wholesale model (Zhen *et al.*, 2022). Second is a study of competitive interactions between online and traditional marketing. Peterson *et al.* analyzed the changes in competition among retailers in traditional channels when there were online retailers and found that the competition between online and traditional channels moderated the competition among retailers in the offline market (Peterson *et al.*, 1997). Yoo *et al.* extended the model to consider the preferences of different users of electronic media. They believed that the introduction of electronic media does not necessarily increase the competition between the two channels (Kauffman *et al.*, 2009). Chiang *et al.* analyzed the competitive relationship between manufacturers and traditional retailers by opening online channels and believed that the opening of online businesses by manufacturers restricted retailers' pricing behavior because its opening eased the double margin of the supply chain (Shih and Chiang, 2005). Fan Xiaojun *et al.* believed that as long as consumers' acceptance of online channels is high enough, both manufacturers and traditional retailers can benefit from the introduction of online business (Gupta *et al.*, 2020). But Bin *et al.* acknowledge that the two charging strategies can alleviate the conflict between the two channels (Xu *et al.*, 2014). Third is a study of the impact of piracy on manufacturer profits: In terms of empirical research, Papies *et al.* studied the effect of piracy on the sales of music CDs and estimated that the loss caused by piracy in the music industry was about 6.6% (Oberholzer-Gee and Strumpf, 2007). Zentner found that the emergence of online piracy caused the sales of music products to drop by 30% (Zentner, 2006). In terms of model research, some scholars acknowledge that due to the network externality of information products, piracy may increase profits. Piracy has a sample effect, and users have the possibility of repurchasing genuine products after trying pirated versions (Tyrowicz *et al.*, 2020).

Although the existing research has given some management implications, when studying the sales model of online channels, only a few works of literature consider the changes in the sales volume of offline and online channels under digital piracy. The cannibalism effect ignores the positive side of online marketing compared with offline marketing. As a result, the existing literature did not consider three important aspects of promoting online marketing. Firstly, if the differences in manufacturers' and online retailers' pricing and profits strategies with/without considered SEs. Secondly, whether the determination of piracy regulation is always a catalyst for online channel participants or not. Thirdly, the judgment of the essential condition that can achieve optimal online channel participants (sales model) with/without considering SEs.

Regarding the gap mentioned above, this paper focuses on the actual situation of online sales information. This research aim is to optimize the optimal sales model of online channel supply chain participants under the influence of SE when digital piracy and participants achieve win-win conditions. Finally, this paper explores the optimal online channel sales model of particular information products considering the influence of SE, which can promote relevant theoretical research to a certain extent.

2. Model description

An online channel supply chain consists of information product manufacturers and online retailers. Manufacturers provide digital information products to consumers through online retailers. Consumers can also digitally download pirated products through illegal channels due to the low cost of disseminating and easy copying of digital information products.

2.1 Consumers' needs

Without loss of generality, let the quality of genuine information products be 1, and the quality of pirated copies be θ (the overall symbol of notation is given in Appendix). Since pirated products often lack some attribute information, for example, pirated music products do not have song names and artist names, this paper believes that the quality of pirated products is lower than that of genuine products (Bian and Veloutsou, 2017; Wee *et al.*, 1995), that is, $0 < \theta < 1$. The user's valuation v of information product quality is assumed to be heterogeneous, and v obeys a uniform distribution on [0, 1]. The utility obtained by consumers by purchasing genuine information products is $v-p$, and the utility obtained by consumers using pirated products is θ_{v-r}. Among them, p is the retail price of authentic information products. Considering that pirated products are generally free, r is set of the piracy supervision intensity, including the cost of obtaining pirated products for consumers and the risk of being punished for being pirated when detected.

According to consumers' attitudes toward piracy, consumers are divided into ethical consumers and ordinary consumers (Kuokkanen and Sun, 2019; de Pelsmacker *et al.*, 2005). Ethical consumers have vital ethical and moral concepts and a strong preference for genuine products. They never use pirated products; ordinary consumers do not have particular intellectual property ethics concepts, and they are more sensitive to product prices than ethical consumers. By comparing the magnitude of the utility of the products obtained, the products with high utility are selected. Assume that the proportion of ethical consumers in the market is λ, and the ratio of ordinary consumers is $1-\lambda$.

Consumers' purchasing decisions are based on rationality and incentive compatibility constraints, as shown in Figure 1.

For ethical consumers, there are two choices: buying genuine; and not buying (inconvenient). The conditions for choosing to buy genuine are:

$$v - p > 0 \Rightarrow v > p \tag{1}$$

For ordinary consumers, the conditions for choosing to use genuine (authentic) products and pirated (copied) products are as follows:

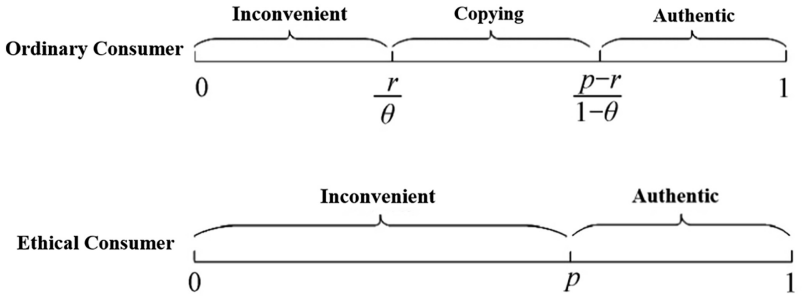

Figure 1.
Consumer online product selection information

$$\left.\begin{array}{l} v-p>0 \Rightarrow v>p \\ v-p>\theta v-r \Rightarrow v>\dfrac{p-r}{1-\theta} \end{array}\right\} \tag{2}$$

$$\left.\begin{array}{l} \theta v-r>0 \Rightarrow v>\dfrac{r}{\theta} \\ \theta v-r>v-p \Rightarrow v<\dfrac{p-r}{1-\theta} \end{array}\right\} \tag{3}$$

According to the purchasing conditions of ethical consumers and ordinary consumers, the demand for genuine and pirated products is as follows:

$$D_L=\begin{cases} (1-\lambda)(1-p)+\lambda\left(1-\dfrac{p-r}{1-\theta}\right) \\ p>\dfrac{r}{\theta} \\ (1-p), \text{Otherwise} \end{cases} \tag{4}$$

$$D_I=\begin{cases} \lambda\left(\dfrac{p-r}{1-\theta}-\dfrac{r}{\theta}\right), p>\dfrac{r}{\theta} \\ 0, \text{Otherwise} \end{cases} \tag{5}$$

Since this paper mainly discusses the coexistence of pirated copies and genuine copies in the market, only the case $p>\frac{r}{\theta}$ is considered.

2.2 Profit and pricing function

Information product manufacturers have two types of sales models: wholesale and agency. In the wholesale model, the manufacturer sets the wholesale price w of the information product. The online retailer obtains the information product from the manufacturer at the wholesale price and sells it to the consumer at the retail price p. In the agency model, the manufacturer sets the retail price p of the product, and the online retailer receives a commission according to the transaction amount ratio α. Since e-book platforms such as Amazon or iBooks often sign long-term contracts with multiple book publishers, this paper assumes that α is an exogenous variable.

Suppose the manufacturer also sells information products through traditional channels. This article assumes that manufacturers sell offline and digital information products through traditional and online media. For example, book publishers sell e-books online and paper books through traditional bookstores. Film producers sell through online video platforms. Regarding the online movies and offline movie DVDs, assuming that there are no online channels, the primary demand for products in traditional media is Q. Since the retail price of information products in traditional media is often affected by fixed costs, such as the retail price of books is mainly affected by printing costs, logistics costs and store rents, it is assumed that the price of information products in traditional channels is an external variable. For generality, normalize it to 1.

When there are online channels, the demand for online channels has an SE on the demand of traditional channels. The demand for online channels includes genuine copies and the demand for pirated copies. The lower the quality of online channel products, the smaller the SE on demand from traditional channels. For example, pirated digital music is not as good as genuine sound quality, integrity and experience, and pirated e-books often appear garbled.

Therefore, the SE of demand for pirated products on traditional channels is lower than that of genuine products. Let τ represent the SE of genuine online channel demand on traditional channel demand. $\theta\tau$ is the SE of digital pirated online channel demand on traditional channel demand, then the demand for information products in traditional channels becomes $Q + \tau D_L + \theta_\tau D_I$. If $\tau < -1$, the negative SE of online channel demand on traditional channel demand is too strong, then manufacturers will not open online channels; in addition, Chen *et al.* believe that the positive SE of online channels on traditional channels will not be too big (Chen *et al.*, 2023). Therefore, consistent with the study, let $-1 < \tau < 1$. The supply chain structure is shown in Figure 2.

To focus on the online channel supply chain, let Q and τ be exogenous variables. To sum up, assuming that the marginal cost of information products is negligible, if the online channel adopts the wholesale model, the profit functions of the manufacturer and the online retailer are:

$$\pi_M = 1 \times [Q + \tau(D_L + \theta D_I)] + wD_L \tag{6}$$

$$\pi_R = (p - w)D_L \tag{7}$$

Items 1 and 2 in Equation (6) are the profits obtained by manufacturers from traditional channels and online channels, respectively.

If the online channel adopts the agency model, the profit functions of the manufacturer and the online retailer are:

$$\pi_M = 1 \times [Q + \tau(D_L + \theta D_I)] + (1 - \alpha)pD_L \tag{8}$$

$$\pi_R = \alpha pD_L \tag{9}$$

3. Equilibrium conditioning model

This paper considers four situations to analyze the influence of SEs on the online channel sales model of information products (as shown in Table 1): First situation: WN represents the wholesale model without considering the SE. Second situation: AN represents the agency model without considering the SE. Third situation: WS represents the wholesale mode when

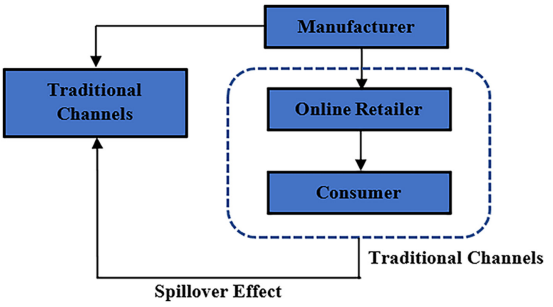

Figure 2.
Schematic diagram of supply chain structure with SE and without SE

	No SEs	Has SEs
Wholesale model	WN	WS
Proxy model	AN	AS

Table 1.
Wholesale model and proxy model with SE and without SE

SEs are considered. Fourth situation: AS represents the agency mode when SEs are considered.

Next, we analyze the game equilibrium under WN, AN, WS and AS, respectively.

3.1 Manufacturers' and online retailers' pricing and profit strategies without considered SEs

WN mode section considers the equilibrium in wholesale mode when there is no SE. Manufacturers and online retailers are subject to a two-stage Stackelberg game theory (Xu *et al.*, 2020). In the first stage, the manufacturer first decides the wholesale price w of the product offered to the online retailer. In the second stage, the online retailer decides the retail price p. According to the relationship between D_L and p, the decision function of the manufacturer and the online retailer is expressed as the following decision function containing only the retail price p and the wholesale price w:

$$\max_{w} \pi_M^{WN} = w\left[(1-\lambda)(1-p) + \lambda\left(1 - \frac{p-r}{1-\theta}\right)\right] + Q \tag{10}$$

$$\max_{p} \pi_R^{WN} = (p-w)\left[(1-\lambda)(1-p) + \lambda\left(1 - \frac{p-r}{1-\theta}\right)\right] \tag{11}$$

In the wholesale model, without considering the SE and the optimal decision of online channel participants, the equilibrium wholesale price of the manufacturer and the equilibrium retail price of the online retailer are:

$$p^{WN^*} = \frac{3(1+r\lambda-\theta)}{4(1+\theta\lambda-\theta)} \tag{12}$$

$$w^{WN^*} = \frac{1+r\lambda-\theta}{2(1+\theta\lambda-\theta)} \tag{13}$$

The equilibrium demand for genuine products and the equilibrium profit for the manufacturer are:

$$D_L^{WN^*} = \frac{1+r\lambda-\theta}{4(1-\theta)} \tag{14}$$

$$\pi_M^{WN^*} = \frac{r\lambda(2-2\theta+r\lambda)(1-\theta)^2}{8(1-\theta)(1-\theta+\theta\lambda)} + Q \tag{15}$$

The equilibrium profit made by the online retailer is:

$$\pi_R^{WN^*} = \frac{(1+r\lambda-\theta)^2}{16(1-\theta)(1-\theta+\theta\lambda)} \tag{16}$$

The manufacturer's wholesale price gives the second derivative concerning the retail price by the online retailer. Therefore,

$$\frac{\partial^2 \pi_R^{WN}}{\partial p^2} = -\frac{2(1-\theta+\theta\lambda)}{1-\theta} < 0$$

It can be easily said that $\pi_R^{WN^*}$ is a concave function of p. According to the inverse solution method, the first derivative of the retailer's decision function is obtained, and the reaction function of the retail price on the wholesale price is obtained.

$$p = \frac{1-\theta+r\lambda}{2(1-\theta+\theta\lambda)} + \frac{w}{2}$$

Substituting it into the manufacturer's decision function and taking the second derivative,

$$\frac{\partial^2 \pi_R^{WN}}{\partial p^2} = -\frac{1-\theta+\theta\lambda}{1-\theta} < 0$$

Therefore, π_M^{WN} is a concave function of p, and there is a unique equilibrium solution for both decision functions, and the equilibrium solution is obtained.

AN mode: This section considers the equilibrium in the proxy mode when there is no SE. In this model, the online retailer only takes a fixed commission percentage, and the manufacturer has the decision-making power over the retail price. According to the relationship between D_L and p, the manufacturer's decision function is expressed as the following decision function containing only the retail price p:

$$\max_p \pi_M^{WN} = (1-\alpha)p\left[(1-\lambda)(1-p) + \lambda\left(1-\frac{p-r}{1-\theta}\right)\right] + Q \tag{17}$$

According to the manufacturer's profit maximization goal, without considering the agency model of SE, in the optimal decision of online channel participants, the manufacturer's equilibrium retail price and the equilibrium demand for genuine products are:

$$p^{AN^*} = \frac{1+r\lambda-\theta}{2(1+\theta\lambda-\theta)} \tag{18}$$

$$D_L^{AN^*} = \frac{1+r\lambda-\theta}{2(1-\theta)} \tag{19}$$

The equilibrium profits achieved by the manufacturer and the online retailer are:

$$\pi_M^{AN^*} = \frac{(1-\alpha)(1+r\lambda-\theta)^2}{4(1-\theta)(1-\theta+\theta\lambda)} + Q \tag{20}$$

$$\pi_R^{AN^*} = \frac{\alpha(1+r\lambda-\theta)^2}{4(1-\theta)(1-\theta+\theta\lambda)} \tag{21}$$

The manufacturer's second derivative concerns the retail price.

$$\frac{\partial \pi_M^{AN}}{\partial p^2} = -\frac{2(1-\alpha)(1-\theta+\theta\lambda)}{1-\theta} < 0$$

Knowing that π_M^{AN} is a concave function of p, there is a unique equilibrium solution for the decision function, which is obtained.

3.2 Manufacturers' and online retailers' pricing and profits strategies with considered SEs

WS model: This section considers the equilibrium under the wholesale model when there are SEs. Manufacturers and online retailers obey a two-stage Stackelberg game theory (Jiang and Chen, 2017). In the first stage, the manufacturer first decides the wholesale price w of the product offered to the online retailer. In the second stage, the online retailer decides the retail price p. According to the relationship between D_L and p, the decision function of the manufacturer and the online retailer is expressed as the following decision function containing only the retail price p and the wholesale price w:

$$\max_{w} \pi_M^{WS} = w\left[(1-\lambda)(1-p) + \lambda\left(1 - \frac{p-r}{1-\theta}\right)\right] + \tau\left[(1-\lambda)(1-p) + \lambda\left(1 - \frac{p-r}{1-\theta}\right)\right] + \theta\lambda\left[\left(\frac{p-r}{1-\theta} - \frac{r}{\theta}\right)\right] + Q \tag{22}$$

$$\max_{p} \pi_R^{WS} = (p-w)\left[(1-\lambda)(1-p) + \lambda\left(1 - \frac{p-r}{1-\theta}\right)\right] \tag{23}$$

Use the reverse order induction method to solve the decision-making problem of each member. In the wholesale mode considering the SE, in the optimal decision-making of online channel participants, the equilibrium wholesale price of the manufacturer and the equilibrium retail price of the online retailer are:

$$w^{WS^*} = \frac{(1-\theta)(1-\tau) + r\lambda}{2(1-\theta+\theta\lambda)} \tag{24}$$

$$p^{WS^*} = \frac{(1-\theta)(3-\tau) + 3r\lambda}{4(1-\theta+\theta\lambda)} \tag{25}$$

The equilibrium demand for genuine products and the equilibrium profits for manufacturers and online retailers are:

$$D_L^{WS^*} = \frac{(1-\theta)(1+\tau) + r\lambda}{4(1-\theta)} \tag{26}$$

$$\pi_M^{WS^*} = \frac{\left[\{r\lambda(2-2\theta+r\lambda) + 2\tau(1-\theta)\} \times \left\{(1-\theta-3r\lambda+4\theta\lambda) + (1-\theta)^2\right\} \times (1+\tau^2)\right]}{8(1-\theta)(1-\theta+\theta\lambda)} + Q \tag{27}$$

$$\pi_R^{WS^*} = \frac{[r\lambda + (1-\theta)(1+\tau)]^2}{16(1-\theta)(1-\theta+\theta\lambda)} \tag{28}$$

The manufacturer's wholesale price gives the second derivative concerning the retail price by the online retailer:

$$\frac{\partial^2 \pi_R^{WS}}{\partial p^2} = -\frac{2(1-\theta+\theta\lambda)}{1-\theta} < 0$$

But π_R^{WS} is a concave function of p. According to the inverse solution method, the first derivative of the retailer's decision function is obtained, and the reaction function of the retail price on the wholesale price is obtained.

$$p = \frac{1-\theta+r\lambda}{2(1-\theta+\theta\lambda)} + \frac{w}{2}$$

Substituting it into the manufacturer's decision function and taking the second derivative:

$$\frac{\partial^2 \pi_M^{WS}}{\partial w^2} = -\frac{1-\theta+\theta\lambda}{1-\theta} < 0$$

Therefore, π_M^{WS} is a concave function of p, and there is a unique equilibrium solution for both decision functions. The equilibrium solution is obtained.

AS mode: This section considers the equilibrium in the proxy mode when there is a SE. In this model, the online retailer only takes a fixed commission percentage, and the manufacturer has the decision-making power over the retail price. According to the relationship between D_L and p, the manufacturer's decision function is expressed as the following decision function containing only the retail price p:

$$\begin{aligned}\max_p \pi_M^{AS} = (1-\alpha)p\left[(1-\lambda)(1-p)+\lambda\left(1-\frac{p-r}{1-\theta}\right)\right] \\ +\tau\left[(1-\lambda)(1-p)+\lambda\left(1-\frac{p-r}{1-\theta}\right)+\theta\lambda\left(\frac{p-r}{1-\theta}-\frac{r}{\theta}\right)\right]+Q\end{aligned} \tag{29}$$

When the SE is considered, in the optimal decision of the supply chain where the manufacturer adopts the proxy mode, the manufacturer's equilibrium retail price and the equilibrium demand for genuine products are:

$$p^{AS*} = \frac{(1-\alpha)(1-\theta+r\lambda)-(1-\theta)\tau}{2(1-\alpha)(1+\theta\lambda-\theta)} \tag{30}$$

$$D_L^{AS*} = \frac{r\lambda-\alpha(1+r\lambda-\theta)+(1-\theta)(1+\tau)}{2(1-\alpha)(1-\theta)} \tag{31}$$

The equilibrium profits achieved by the manufacturer and the online retailer are:

$$\pi_M^{AS*} = \frac{\left[(1-\theta)^2\tau^2+2(1-\alpha)(1-\theta)\right]\times\left[(1-\theta-r\lambda+2\theta\lambda)\tau+(1-\alpha)^2\right]\times(1+r\lambda-\theta)^2}{[4(1-\alpha)(1-\theta)]\times(1+\theta\lambda-\theta)}+Q \tag{32}$$

$$\pi_R^{AS*} = \frac{\alpha\left[(1-\alpha)^2(1+r\lambda+\theta)^2-(1-\theta)^2\tau^2\right]}{4(1-\alpha)^2(1-\theta)(1+\theta\lambda-\theta)} \tag{33}$$

The manufacturer's second derivative with respect to the retail price:

$$\frac{\partial^2\pi_M^{AS}}{\partial p^2} = -\frac{2(1-\alpha)(1-\theta+\theta\lambda)}{1-\theta} < 0$$

The manufacturer's second derivative concerning the retail price: Knowing that π_M^{AS} is a concave function about p, there is a unique equilibrium solution for the decision function, and the equilibrium solution is obtained.

By solving the game equilibrium of the participants in the four modes, the optimal pricing decisions of the participants in different modes are given, respectively. When doing the above analysis, analyze the impact of piracy on the sales model of online channel participants. It is assumed that consumers have a demand for both genuine and pirated copies. The model needs to meet the following assumptions:

$$r < \min\left\{\frac{\theta-\theta^2}{2-2\theta+\theta\lambda}, \frac{\theta(1-\theta)(3-\tau)}{4-4\theta+\theta\lambda}, \frac{(1-\theta)\theta(1-\alpha-\tau)}{(1-\alpha)(2-2\theta+\theta\lambda)}, \theta \text{ Where } \alpha < 1-\tau\right.$$

4. Model comparison analysis of manufacturers' and online retailers' pricing and profits strategies with/without considered SEs

4.1 Comparative analysis of WN model and WS model without SE

(1) Wholesale model 1: *If* $\tau > 0, w^{WS^*} < w^{WN^*}, p^{WS^*} < p^{WN^*}, D_L^{WS^*} > D_L^{WN^*}, \pi_M^{WS^*} > \pi_M^{WN^*}, \pi_R^{WS^*} > \pi_R^{WN^*}$

(2) Wholesale model 2: *If* $\tau < 0, w^{WS^*} > w^{WN^*}, p^{WS^*} > p^{WN^*}, D_L^{WS^*} < D_L^{WN^*}, \pi_M^{WS^*} < \pi_M^{WN^*}, \pi_R^{WS^*} < \pi_R^{WN^*}$

Proof:

$$w^{WS^*} - w^{WN^*} = -\frac{(1-\theta)\tau}{2(1-\theta+\theta\lambda)}$$

$$p^{WS^*} - p^{WN^*} = -\frac{(1-\theta)\tau}{4(1-\theta+\theta\lambda)}$$

$$D_L^{WS^*} - D_L^{WN^*} = \frac{\pi}{4}$$

$$\pi_M^{WS^*} - \pi_M^{WN^*} = \frac{[(1-\theta)\tau + 2 - 2\theta - 6r\lambda + 8\lambda]\tau}{8(1-\theta+\theta\lambda)}$$

$$\pi_M^{WS^*} - \pi_R^{WN^*} = \frac{[2 - 2\theta + 2r\lambda + (1-\theta)\tau]\tau}{16(1-\theta+\theta\lambda)}$$

Therefore, When $\tau > 0, \pi_M^{WS^*} > \pi_M^{WN^*}, \pi_M^{WS^*} > \pi_R^{WN^*}$; When $\tau < 0, \pi_M^{WS^*} < \pi_M^{WN^*}, \pi_M^{WS^*} < \pi_R^{WN^*}$

Compared with ignoring the spillover effect in the wholesale mode, the positive spillover effect will prompt the online channel members to lower the price, expand the demand and thus obtain more excellent benefits. In contrast, the negative spillover effect will lead to an increase in online channel members. Price, demand propotional to the revenue, which means price, demand decreases if revenue decreases. It is because, in the wholesale mode, the positive spillover effect enhances the cooperative relationship between the members of the supply chain of the online channel and promotes the increase of the profits of both parties.

4.2 Comparative analysis of AN model and AS model with SE

(1) Proxy model 1: *if* $\tau > 0, p^{AS*} < p^{AN^*}, D_L^{AS*} > D_L^{AN^*}, \pi_M^{AS*} > \pi_M^{AN^*}$

(2) Proxy model 2: *if* $\tau < 0, p^{AS*} > p^{AN^*}, D_L^{AS*} < D_L^{AN^*}, \pi_M^{AS*} < \pi_M^{AN^*}$

(3) Proxy model 3: $\pi_R^{AS*} > \pi_R^{AN^*}$ Always $\tau > 0$

Proof:

$$p^{AS*} - p^{AN^*} = -\frac{\tau(1-\theta)}{2(1-\alpha)(1-\theta+\theta\lambda)}$$

$$D_L^{AS*} - D_L^{AN^*} = \frac{\tau}{2-2\alpha}$$

Therefore, When $\tau > 0, p^{AS*} < p^{AN^*}, D_L^{AS*} > D_L^{AN^*}$; When $\tau < 0, p^{AS*} > p^{AN^*}, D_L^{AS*} < D_L^{AN^*}$

$$\pi_M^{AS*} - \pi_M^{AN^*} = \frac{[(2-2\alpha+\tau)(1-\theta)+2\lambda(2\theta-r)(1-\alpha)]\tau}{4(1-\alpha)(1-\theta+\theta\lambda)}$$

Where:

$$2-2\alpha+\tau > 0$$

$$(2-2\alpha+\tau)(1-\theta)+2\lambda(2\theta-r)(1-\alpha) > 0$$

Therefore, When $\tau > 0, \pi_M^{AS*} > \pi_M^{AN^*}$; When $\tau < 0, \pi_M^{AS*} < \pi_M^{AN^*}$

$$\pi_R^{AS*} - \pi_R^{AN^*} = \frac{\alpha(1-\theta)\tau^2}{4(1-\alpha)^2(1-\theta+\theta\lambda)}$$

Therefore, When $\tau > 0, \pi_R^{AS*} > \pi_R^{AN^*}$

Under the agency model, compared with not considering the spillover effect, the positive spillover effect will lead to lower retail prices, expand demand and thus obtain more excellent benefits for the manufacturer. In contrast, the negative spillover effect will raise prices, lower demand and reduce revenue. For online retailers, no matter whether the spillover effect is positive or negative, their profits will be improved as long as there is a spillover effect. Similar to Proposition 5, in the agency model, positive spillover effects can also enhance the cooperative relationship between members of the online channel supply chain; in addition, since the price increase caused by the negative spillover effect is enough to offset the loss caused by the decrease in online demand, so negative spillovers can also boost online retailers' profits.

4.3 Comparative analysis of WN model and AN model without SE

(1) WN model without the spillover effect: $\frac{\delta\pi_M^{WN^*}}{\delta r} > 0, \frac{\delta\pi_R^{WN^*}}{\delta r} > 0$

(2) AN model without the spillover effect: $\frac{\delta\pi_M^{WN^*}}{\delta r} > 0, \frac{\delta\pi_R^{WN^*}}{\delta r} > 0$

Proof:

$$\frac{\delta\pi_M^{WN^*}}{\delta r} = \frac{\lambda(1-\theta+r\lambda)}{4(1-\theta)(1-\theta+\theta\lambda)} > 0$$

$$\frac{\delta\pi_R^{WN^*}}{\delta r} = \frac{\lambda(1-\theta+r\lambda)}{8(1-\theta)(1-\theta+\theta\lambda)} > 0$$

$$\frac{\delta\pi_M^{AN^*}}{\delta r} = \frac{\lambda(1-\alpha)(1-\theta+r\lambda)}{2(1-\theta)(1-\theta+\theta\lambda)} > 0$$

$$\frac{\delta\pi_R^{AN^*}}{\delta r} = \frac{\alpha\lambda(1-\theta+r\lambda)}{2(1-\theta)(1-\theta+\theta\lambda)} > 0$$

When spillover effects are not considered, regardless of the manufacturer's adopted sales model, the intensity of piracy regulation always promotes the profits of online channel members. The results reveal that manufacturers and online retailers should urge policymakers to improve legal systems, increase crackdowns and impose heavy fines to increase piracy supervision. Technological preventive measures can also increase the cost and difficulty of piracy and limit illegal copies.

(1) When spillover effects are not considered for manufacturers: $if\ 0 < \alpha < \frac{1}{2}, \pi_M^{WN^*} < \pi_M^{AN^*}$; $if\ \frac{1}{2} < \alpha < 1, \pi_M^{WN^*} > \pi_M^{AN^*}$

(2) When spillover effects are not considered for online retailers: $if\ 0 < \alpha < \frac{1}{4}, \pi_R^{WN^*} > \pi_R^{AN^*}$; $if\ \frac{1}{4} < \alpha < 1, \pi_R^{WN^*} < \pi_R^{AN^*}$

Proof:

$$\pi_M^{WN^*} - \pi_M^{AN^*} = -\frac{(1-2\alpha)(1-\theta+r\lambda)^2}{8(1-\theta)(1-\theta+\theta\lambda)}$$

Therefore, $if\ 0 < \alpha < \frac{1}{2}, \pi_M^{WN^*} < \pi_M^{AN^*}$; $if\ \frac{1}{2} < \alpha < 1, \pi_M^{WN^*} > \pi_M^{AN^*}$

$$\pi_R^{WN^*} - \pi_R^{AN^*} = \frac{(1-4\alpha)(1-\theta+r\lambda)^2}{8(1-\theta)(1-\theta+\theta\lambda)}$$

Therefore, $if\ 0 < \alpha < \frac{1}{4}, \pi_R^{WN^*} > \pi_R^{AN^*}$; $if\ \frac{1}{4} < \alpha < 1, \pi_R^{WN^*} < \pi_R^{AN^*}$

When the commission ratio is small, the manufacturer prefers the agency model to the wholesale model. The online retailer prefers the agency model when the commission ratio is large. It shows that manufacturers and online retailers have different sales model tendencies. A lower commission ratio reduces online retailers' revenue share, which benefits manufacturers. A higher commission ratio is beneficial to online retailers.

Regardless of spillover effects, when $1/4 < \alpha < 1/2$, both manufacturers and online retailers tend to agency mode. The manufacturer and the online retailer obtain higher profits in the agency mode compared with the wholesale mode when the commission ratio satisfies $1/4 < \alpha < 1/2$. Because the agency mode slows down the double marginal effect of the supply chain, when the commission ratio is moderate, the profit of the entire supply chain is improved, and both the manufacturer and the online retailer obtain higher income through sharing.

4.4 Comparative analysis of WS model and AS model with SE

(1) WS model with spillover effects: $\frac{\delta\pi_R^{WS^*}}{\delta r} > 0$; $if\ \tau < \frac{1}{3}, \frac{\delta\pi_M^{WS^*}}{\delta r} > 0$; $if\ \tau > \frac{1}{3}$, $r < \min\left[\frac{\theta(1-\theta)(3-\tau)}{4-4\theta+\theta\lambda}, \frac{(1-\theta)(3\tau-1)}{\lambda}\right], \frac{\delta\pi_M^{WS^*}}{\delta r} < 0$

(2) AS model with spillover effects: $\frac{\delta\pi_M^{AS*}}{\delta r} > 0, \frac{\delta\pi_R^{AS*}}{\delta r} > 0$

Proof:

$$\frac{\delta \pi_M^{WS^*}}{\delta r} = \frac{\lambda[(1-\theta)(1-3\tau)+r\lambda]}{4(1-\theta)(1-\theta+\theta\lambda)}$$

Therefore, $if\, \tau < \frac{1}{3}, \frac{\delta \pi_M^{WS^*}}{\delta r} > 0;\ \tau > \frac{1}{3}, r < \min\left[\frac{\theta(1-\theta)(3-\tau)}{4-4\theta+\theta\lambda}, \frac{(1-\theta)(3\tau-1)}{\lambda}\right], \frac{\delta \pi_M^{WS^*}}{\delta r} < 0$

$$\frac{\delta \pi_R^{WS^*}}{\delta r} = \frac{\lambda[(1-\theta)(1+\tau)+r\lambda]}{8(1-\theta)(1-\theta+\theta\lambda)} \quad -1 < \tau < 1$$

$$\text{Therefore}, \frac{\delta \pi_R^{WS^*}}{\delta r} > 0$$

$$\frac{\delta \pi_M^{AS*}}{\delta r} = \frac{\lambda[(1-\alpha-\tau)(1-\theta)+r\lambda(1-\alpha)]}{2(1-\theta)(1-\theta+\theta\lambda)} \quad \alpha+\tau < 1$$

$$\frac{\delta \pi_R^{AS*}}{\delta r} = \frac{\alpha\lambda(1-\theta+r\lambda)}{2(1-\theta)(1-\theta+\theta\lambda)} > 0$$

Therefore, $\frac{\delta \pi_M^{AS*}}{\delta r} > 0$

Under the wholesale model considering spillover effects, piracy supervision always has a positive effect on online retailers' profits. For manufacturers, piracy supervision can promote their profits when the spillover effect is negligible. But when the spillover effect is significant, the enhancement of piracy supervision cannot bring about an increase in profits. However, under the agency model, piracy supervision will always promote the profits of online channel members. The results reveal that the existence of piracy can not only erode the demand for genuine online channels, but at the same time, the demand for genuine and pirated online channels has a spillover effect on the demand for traditional channels. In the wholesale and retail mode, piracy and genuine competition model, and the cannibalization effect on the genuine version alleviate the supply chain's double marginal effect to a certain extent. Balance between. When the spillover effect is small, the supervision of piracy should be strengthened reasonably. When the spillover effect is exist, appropriate control of the supervision of piracy will enable manufacturers to obtain more profit. And because the agency model effectively coordinates the supply chain compared with the wholesale model, online channel participants have a consistent attitude toward piracy control and tend to strengthen piracy supervision.

When the spillover effect $\tau < \tau_1$ or $\tau < \tau_2$, the manufacturer tends to adopt the agency model. When the spillover effect satisfies $\tau_1 < \tau < \tau_2$, the manufacturer tends to adopt the wholesale mode. Where:

$$\tau_1 = \frac{\left(\alpha - 1 - \alpha\sqrt{2-2\alpha}\right)(1-\theta+r\lambda)}{(1+\alpha)(1-\theta)}$$

$$\tau_2 = \frac{\left(\alpha - 1 + \alpha\sqrt{2-2\alpha}\right)(1-\theta+r\lambda)}{(1+\alpha)(1-\theta)}$$

Proof:

$$\Delta_M^{S*} = \pi_M^{AS*} - \pi_M^{WS^*} = \frac{\left[(1+\alpha)(1-\theta)^2\tau^2 + 2(1-\alpha)(1-\theta)(1-\theta+r\lambda)\tau + (1-\alpha)(1-2\alpha)(1+r\lambda-\theta)^2\right]}{8(1-\alpha)(1-\theta)(1+\theta\lambda-\theta)}$$

Therefor, $if\,\tau_1 < \tau < \tau_2, \Delta_M^{S*} < 0$; $if\,\tau < \tau_1$ or $\tau > \tau_2, \Delta_M^{S*} > 0$

When the spillover effect is noticeable (large or small), manufacturers tend to adopt the agency model; otherwise, they tend to adopt the wholesale model. It is because in the wholesale mode, when the spillover effect is enormous, manufacturers are more motivated to expand the demand in online channels by reducing wholesale prices, thereby expanding the demand in traditional channels. But since the online channel is the only source of profit for online retailers, it does not reduce retail prices, thus intensifying the double marginal effect and harming the interests of manufacturers. When the spillover effect is minimal, manufacturers start from the overall interests. To avoid the adverse impact of online demand on traditional demand, manufacturers reduce online channel demand by increasing wholesale prices. But online retailers have no incentive to increase retail prices. Therefore, when the spillover effect is more prominent (larger or smaller), it is more beneficial for the manufacturer to adopt the agency model.

Online retailers tend to adopt the agency model when the spillover effect satisfies $\tau_3 < \tau < \tau_4$ them. When the spillover effect $\tau < \tau_3$ or $\tau > \tau_4$, they tend to adopt the wholesale model. Where:

$$\tau_3 = \frac{(1-\alpha)\left(\alpha - 1 - 2\alpha\sqrt{2+\alpha}\right)(1-\theta+r\lambda)}{(1+\alpha)^2(1-\theta)}$$

$$\tau_3 = \frac{(1-\alpha)\left(\alpha - 1 + 2\alpha\sqrt{2+\alpha}\right)(1-\theta+r\lambda)}{(1+\alpha)^2(1-\theta)}$$

Proof:

$$\Delta_R^{S*} = \pi_R^{AS*} - \pi_R^{WS^*} = \frac{-\left[(1+\alpha)^2(1-\theta)^2\tau^2 + 2(1-\alpha)^2(1-\theta)(1-\theta+r\lambda)\tau + (1-\alpha)^2(1-4\alpha)(1+r\lambda-\theta)^2\right]}{16(1-\alpha^2)(1-\theta)(1+\theta\lambda-\theta)}$$

Therefore, $if\,\tau_3 < \tau < \tau_4, \Delta_R^{S*}$; $if\,\tau < \tau_3$ or $\tau > \tau_4, \Delta_M^{S*} < 0$

When the spillover effect is noticeable (large or small), online retailers tend to adopt the wholesale model and obtain the decision-making power of the terminal retail price; otherwise, they tend to adopt the agency model. It is because in the wholesale mode, manufacturers try to expand the demand for online channels by reducing wholesale prices, and online retailers have the right to decide about retail prices. It is more advantageous to choose the wholesale model for the income obtained by sharing the revenue in the agency model; when the spillover effect is minimal, manufacturers can reduce the demand for online channels by increasing wholesale prices to avoid the adverse impact of online demand on traditional demand. Online retailers can reduce the retail price to minimize the losses due to reduced demand. So, when the spillover effect is noticeable (large or small), it is more beneficial for online retailers to adopt the wholesale model.

If $0 < \alpha < \frac{7}{9}$, when the spillover effect satisfies $\tau_2 < \tau < \tau_4$, both online retailers and manufacturers tend to adopt agency mode. Online retailers and manufacturers tend to adopt the wholesale model when the spillover effect satisfies $\tau_1 < \tau < \tau_3$ them. Where $\tau_1 < \tau_3 < \tau_2 < \tau_4$.

Proof:

$$\tau_3 - \tau_1 = \frac{\alpha(1-\theta+r\lambda)\left[(1+\alpha)\sqrt{2-2\alpha} - 2(1-\alpha)\left(\sqrt{2+\alpha}-1\right)\right]}{(1+\alpha)^2(1-\theta)}$$

Therefore, When $0 < \alpha < 1, \tau_3 > \tau_1$

$$\tau_4 - \tau_2 = \frac{\alpha(1-\theta+r\lambda)\left[2(1-\alpha)\left(\sqrt{2+\alpha}+1\right) - (1+\alpha)\sqrt{2-2\alpha}\right]}{(1+\alpha)^2(1-\theta)}$$

Therefore, *if* $0 < \alpha < \frac{7}{9}, \tau_4 > \tau_2$

$$\tau_2 - \tau_3 = \frac{\alpha(1-\theta+r\lambda)\left[2(1-\alpha)\left(\sqrt{2+\alpha}-1\right) + (1+\alpha)\sqrt{2-2\alpha}\right]}{(1+\alpha)^2(1-\theta)} > 0$$

Therefore, $\tau_2 > \tau_3$

When considering spillover effects, both the wholesale and agency models are likely to benefit the interests of online channel participants simultaneously and gain mutual support from both parties. It is different from the determination when spillover effects are not considered. When the commission ratio is constant, and the spillover effect is small, online channel participants can achieve a win-win situation in the wholesale mode. When the spillover effect is significant, they can achieve a win-win situation in the agency model.

5. Condition of optimal online channel sales model with/without considering SEs

The current research uses numerical examples to analyze the influence of commission ratio, piracy supervision and ethical consumer ratio on supply chain members' choice of sales model. First, let $\lambda = 0.8$, $\theta = 0.8$, $r = 0.1$, and the optimal sales model area of online channel participants under the influence of commission ratio and SE is shown in Figure 3(a).

In Region IV, both manufacturers and online retailers tend to choose the agency model. In Region II, they both tend to select the wholesale model. In Regions I and V, the manufacturers choose the agency model, and online retailers select the wholesale model. In Region III, manufacturers tend to prefer the wholesale model, and online retailers choose the agency model. In particular, when the SE is not considered, online channel participants can only achieve a win-win situation in the agency model and achieve Pareto optimality. As the SE decreases, especially when the SE is less than −0.2, the commission ratio is small, and online

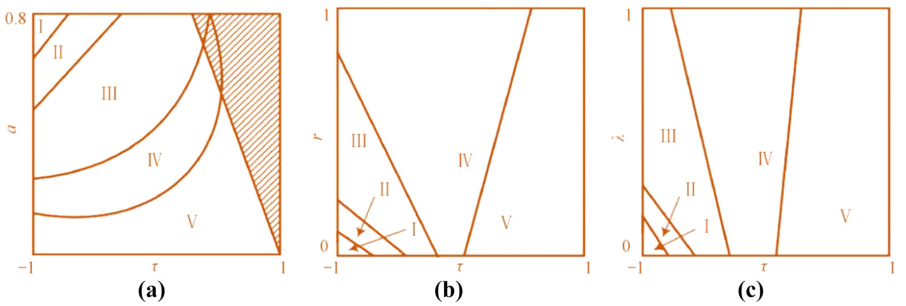

Figure 3.
Optimal sales model for online channel participants

channel participants can achieve a win-win situation in the agency model. If the commission ratio is large, they can achieve a win-win situation in the wholesale model.

Let $\lambda = 0.8$, $\theta = 0.8$, $\alpha = 0.3$; the optimal sales model area of online channel participants under the influence of piracy supervision and SE is shown in Figure 3(b). When the SE is small, piracy supervision significantly impacts the optimal sales model of online channel participants. When the leadership of piracy is weak, online channel participants can achieve a win-win situation in the wholesale model. When the supervision of piracy is strong, they can achieve a win-win situation in the agency model.

Let $r = 0.1$, $\theta = 0.8$, $\alpha = 0.3$; the optimal sales model area of online channel participants under the influence of ethical consumer proportion and SE is shown in Figure 3(c). When the SE is small, the ratio of ethical consumers significantly impacts the optimal sales model of online channel participants. When the proportion of ethical consumers is small, online channel participants can achieve a win-win situation in the wholesale model; when the ratio of ethical consumers is significant, they can achieve a win-win situation in the agency model.

In the above analysis, it is assumed that the retail price of traditional channels is an exogenous variable. This section relaxes this assumption and considers the case where offline retailers determine the retail price. Manufacturers set the wholesale price t of information products in traditional channels, and then traditional retailers set the retail price p. When there is a SE, the demand from the offline market becomes:

$$\bar{Q} = Q + \tau(D_L + \theta D_I) - p_t \tag{34}$$

The traditional retailer's profit $\pi_T = (p_t - w_t)\bar{Q}$. Then, in the wholesale model, the manufacturer's profit $\pi_M = w_t\bar{Q} - wD_L$ is the online retailer's profit $\pi_R = (p - w)D_L$. In the agency model, the manufacturer's profit is:

$$\pi_M = w_t\bar{Q} + (1 - \alpha)pD_L \tag{35}$$

Online retailer profit $\pi_R = \alpha pD_L$.

In the wholesale model, the game sequence is as follows. First, the manufacturer simultaneously decides the wholesale price of the information product in the traditional and online channels. Then, the traditional retailer and the online retailer decide their retail price simultaneously.

In the agency model, first, the manufacturer decides the wholesale price of the product in traditional channels. Then, the offline retailer determines the retail price of the product in the traditional market. Finally, the manufacturer decides the retail price of the product in the online channel. By reverse order induction, equilibrium decisions and profits can be obtained in the two modes. So, it will not be repeated here. The above conclusions have no essential change by comparing the equilibrium results, but there will be a partial shift in the value and range of values.

6. Optimal online sales model

The following criteria mentioned below can achieve the optimal online sales model, which is the research argument mentioned in the introduction part:

According to the result mentioned above, if $\lambda = 0.8$, $\theta = 0.8$, and $r = 0.1$, the optimal sales model of online channel participants can be influenced by the commission ratio. The online channel participants can achieve a win-win situation in the agency model and achieve Pareto optimality if the SE decreases because the commission ratio decreases. The online channel participants can achieve a win-win situation in the wholesale model and achieve Pareto optimality if the SE increases because the commission ratio increases. According to the result

mentioned above, if $\lambda = 0.8$, $\theta = 0.8$, $\alpha = 0.3$, the optimal sales model of online channel participants can be influenced by piracy supervision because SE is minimal. If the leadership of piracy is weak, online channel participants can achieve a win-win situation in the wholesale model. If the leadership of piracy is intense, online channel participants can achieve a win-win situation in the agency model. According to the result mentioned above, if $r = 0.1$, $\theta = 0.8$, $\alpha = 0.3$, the optimal sales model of online channel participants can be influenced by ethical consumer proportion since the SE is minimal. If the proportion of ethical consumers decreases, online channel participants can achieve a win-win situation in the wholesale model. If the proportion of ethical consumers increases, online channel participants can achieve a win-win situation in the agency model.

7. Conclusion

This paper aims at an online channel supply chain of products information including manufacturers and online retailers, aims to measure the SE of online product demand on traditional channel information product demand, analyzes this SE on consumers for ethical and ordinary and analyzes the impact of the supply chain of online channels where the sales model is wholesale or agency. According to whether the SE and different sales models are considered, the wholesale model and agency model without SE and the wholesale model and agency model with SE are constructed, respectively, and the optimal price, demand and profit of online channel participants under different conditions are compared and analyzed. The article has the followings outcomes. Compared with ignoring the SE, if the SE is positive, the manufacturer's profit in wholesale and agency modes will increase. If the SE is negative, the net profit will decrease accordingly. For online retailers, their profit changes under the wholesale model are the same as those of the manufacturer, and under the agency model, spillovers can always boost their profits. When SEs are not considered, the intensity of piracy regulation always has a positive impact on the profits of online channel participants. When the SE is higher, the intensity of piracy regulation is detrimental to manufacturers. When the SE is not considered, the online channel participants can only achieve a win-win situation in the agency model if the commission ratio is moderate. When the SE is considered, both the wholesale model and the agency model may benefit with the interests of online channel participants at the same time. Especially when the SE is small, if the proportion of commission is large, the supervision of piracy is weak. Also, the ratio of ethical consumers is small, and all online channel participants can achieve a win-win situation in the wholesale model.

This paper is the first exploration of an online sales model for information products when SEs are considered. In reality, manufacturers should conduct sufficient market research on the consumer market, analyze the types and proportions of consumers' attitudes toward piracy and weigh the pros and cons of the two sales models based on piracy supervision and SEs. Online channel participants can achieve a win-win sales model.

8. Limitations and future research

The future research may expand from the following aspects: This paper only considers the case of one online retailer, and the optimal sales model under the competition of two online retailers needs further research. This paper assumes that the traditional channel demand is an exogenous variable. This assumption may relax in the follow-up research, and the interaction between traditional and online channels needs to be analyzed. This paper does not consider the sales price of pirated copies. How will the selling price of pirated copies affect the manufacturer's sales strategy to squeeze the open market? It is also the future research direction of this paper.

9. Research implication

The practical implication of the research is diverse in terms of improving online sales concerning the development of an online supply chain model of the information product. In addition, this research can help to reduce the product price based on the current supply chain method established in this research. The theoretical implication of the research includes the organizational theory, and current research can improve organizational efficiency by improving the sales rate of the product.

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(The Appendix follows overleaf)

Appendix

No.	Symbol	Meaning
1	θ	The quality of pirated products
2	p	The retail price of authentic information products
3	v	The user's valuation
4	λ	Ratio of ethical consumers
5	D_L	Demand for genuine products
6	D_I	Demand for pirated products
7	τ	The spillover effect of genuine online channel demand on traditional channel demand
8	Q	The primary demand for products in traditional media
9	π_M	The profit functions of the manufacturer
10	π_R	The profit functions of the online retailer
11	w	Wholesale price of the information product
12	α	The transaction amount ratio
13	r	The set of the piracy supervision intensity
14	p^{WN^*}	The equilibrium price of the manufacturer in the wholesale model without considering the SE
15	w^{WN^*}	The equilibrium retail price of the online retailer in the wholesale model without considering the SE
16	$D_L^{WN^*}$	The equilibrium demand for genuine products in the wholesale model without considering the SE
17	$\pi_M^{WN^*}$	The equilibrium profit for the manufacturer in the wholesale model without considering the SE
18	$\pi_R^{WN^*}$	The equilibrium profit made by the online retailer in the wholesale model without considering the SE
19	p^{AN^*}	The manufacturer's equilibrium retail price in the agency model without considering the SE
20	$D_L^{AN^*}$	The equilibrium demand for genuine products in the agency model without considering the SE
21	$\pi_M^{AN^*}$	The equilibrium profits achieved by the manufacturer in the agency model without considering the SE
22	$\pi_R^{AN^*}$	The equilibrium profits achieved by the online retailer in the agency model without considering the SE
23	w^{WS^*}	The equilibrium wholesale price of the manufacturer in the wholesale mode when SEs are considered
24	p^{WS^*}	The equilibrium retail price of the online retailer in the wholesale mode when SEs are considered
25	$D_L^{WS^*}$	The equilibrium demand for genuine products in the wholesale mode when SEs are considered
26	$\pi_M^{WS^*}$	The equilibrium profits for manufacturers and online retailers in the wholesale mode when SEs are considered
27	p^{AS^*} -	The manufacturer's equilibrium retail price in the agency mode when SEs are considered
28	$D_L^{AS^*}$	The equilibrium demand for genuine products in the agency mode when SEs are considered
29	$\pi_M^{AS^*}$	The equilibrium profits achieved by the manufacturer in the agency mode when SEs are considered
30	$\pi_R^{AS^*}$	The equilibrium profits achieved by the online retailer in the agency mode when SEs are considered

Table A1.
The table of notation

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