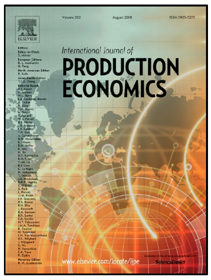

Reward points, profit sharing, and valuable coordination mechanism in the O2O era

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Reward points, profit sharing, and valuable coordination mechanism in the O2O era

ABSTRACT

When the manufacturer opens an online channel to compete with its retailer, effective mechanisms need to be utilized to coordinate the O2O (online to offline) distributions and thus higher profits can be achieved for all supply chain players. We first propose two mechanisms, which are the manufacturer's financial support in reward points to the retailer and the profit sharing, for the supply chain players to employ in order to mitigate the O2O competition and create a Pareto result. Our results show that the manufacturer's financial support in reward points to the retailer mechanism does alleviate the O2O competition and help improve the profit of each supply chain player; however, the retailer is reluctant to cooperate with the manufacturer to implement a profit sharing. We then propose a novel mechanism, which is the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing, to coordinate the O2O distributions. Our results show that such a mechanism effectively solves the issue of O2O competition and creates much higher profits for supply chain players. Furthermore, our results also show that compared to the simultaneous mode, the leader-follower Stackelberg mode provides no competitive advantage to the manufacturer or the retailer when the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing is utilized to coordinate the O2O distributions.

Keywords: Strategies; Reward points; Profit sharing; Channel coordination; O2O competition; Supply chain management

1. Introduction

Nowadays many manufacturers, such as Hewlett & Packard, Lenovo, Dell Computer, Mattel, Pioneer Electronics, P&G, and Haier, are using O2O (online to offline) channels to sell their products to consumers (Tsay and Agarwal, 2004; Chen et al., 2008; Amrouche and Yan, 2012). While more and more manufacturers are distributing their products through O2O channels, their retailers are concerning the O2O competition. Collett (1999) points out that some manufacturers such as Levi Strauss & Co. have stopped selling directly to consumers. Some of Home Depot's manufacturers (e.g. Stanley Works) have given up their online plan after receiving the warning letter from Home Depot (Brooker, 1999). Keenan (1999) gives examples where the manufacturers took steps to explain to the retailers that the opened online channel is targeted to a different market segment. Sometimes, manufacturers use the online channel for information and sales support only, while leaving the actual sales to the retailers (Cohen, 2000). Chiang et al. (2003) show that online channel is not always detrimental to the retailers. Prior research (e.g. Tsay and Agrawal, 2004; Cattani et al., 2006; Yue and Liu, 2006; Mukhopadhyay et al., 2008; Yan, 2011) also propose some other coordinative mechanisms (e.g. sales efforts, information sharing, added retail services, brand differentiation) to alleviate the O2O competition.

In this paper, we first propose two mechanisms, which are the manufacturer's financial support in reward points (i.e. the manufacturer provides a financial support to the retailer to implement a reward points program) to the retailer and the profit sharing, for supply chain players to employ in order to mitigate the O2O competition and create a Pareto result. We then propose a fresh mechanism, which is the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing, to alleviate the O2O competition and help improve the supply chain performance effectively and efficiently, and this mechanism is not currently addressed in the extant literature. We show that the manufacturer and the retailer can utilize this novel mechanism to improve supply chain management and their individual profits effectively and efficiently. Such a mechanism effectively solves the issue of O2O competition and creates higher performances for all supply chain players in the supply chain of manufacturer – retailer O2O distributions.

The reward points program (i.e. the consumers receive and accumulate points based on their purchases and then redeem the earned points for rewards) nowadays becomes increasingly popular in the retail industry. Various retailers, such as Staples, Kohl's, Sears, etc., are actively using reward points programs to sell their products. The offered reward points create a favorable attitude towards a particular retailer and thus motivate consumers to buy from this retailer. Having a well-thought-out reward points program is the key to attracting and stimulating consumers to buy. Generous reward points help increase consumer's willingness to buy and lead to more sales (Taylor and Neslin, 2005). The overall increase in the importance of reward points has motivated us to explore the role and use of reward points in practice. Particularly e-commerce is becoming more and more popular in the business market and significantly reshapes supply chain management. Many manufacturers are using O2O distributions to sell their products directly to consumers, which leads to intensive competition between the O2O channels. The reward points, which help raise retail sales and thereby may bring better returns for all supply chain players, thus can be utilized as an effective mechanism to alleviate the O2O competition and help improve supply chain performance.

In our research, we investigate what effective mechanisms can be utilized to coordinate the O2O distributions when a manufacturer opens an online channel to compete with its retailer. We first propose two mechanisms, which are the manufacturer's financial support in reward points to the retailer and the profit sharing, for the supply chain players to employ in order to mitigate the O2O competition and create a Pareto result. We then propose a novel mechanism, which is the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing, to coordinate the O2O distributions. Given that the manufacturer offers financial support from its own pocket to the retailer to implement the reward points program, it may be tempting to reason that the manufacturer gives some profit concession to its retailer while opening an online channel. Alternatively, when the retailer shares some portion of its profit with the manufacturer, one can expect that the retailer will receive profit reduction. Our model, however, indicates that this reasoning may not always hold. Furthermore, when the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing is employed, we have to ask what will happen. These results are not obvious and obviously need careful study. We thus study all these mechanisms and compare the profits of both the manufacturer and the retailer through considering different scenarios and propose optimal strategies for the manufacturer and the retailer to employ. To the best of our knowledge, our work is the first one in the extant literature to study the strategic role the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing plays in the O2O distributions of the manufacturer – retailer supply chain, given that the product web-compatibility is considered.

Specifically, our research studies the following important questions:

(a) When a manufacturer adds an online channel to compete with its retailer and sell products through O2O channels, what effective mechanisms can be utilized to alleviate the O2O competition and help improve the performances of all supply chain players?

(b) What is the strategic role the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing mechanism plays in the O2O distributions? Given that the product web-compatibility is considered.

(c) How does the value of the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing changes as product web-compatibility changes?

In order to answer these questions, we consider four scenarios: 1) O2O benchmark model, 2) O2O model with the manufacturer's financial support in reward points to the retailer, 3) O2O model with profit sharing, 4) O2O model with the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing. We then compare these scenarios and derive the optimal strategies for the manufacturer and the retailer. Furthermore, we also compare the profits of both the manufacturer and the retailer through considering different behaving modes and propose if there is a more beneficial mode for the manufacturer and the retailer to employ. Hence, the business managers can utilize our findings to make wise investment in coordinating the O2O distributions and employ appropriate mode to improve supply chain efficiency and performance.

The remainder of our paper is organized as follows. Section 2 presents pertinent literature. Sections 3, 4, and 5 analyze the different scenarios and illustrate key results. Conclusions and managerial implications are presented in Section 6.

2. Literature review

2.1. *Value creation in supply chain area*

Many scholars study value creation in the supply chain area. For example, Bowman and Ambrosini (2000) showed that organization members create value and the firm profit (the proportion of value captured by the firm) also can be attributed to the actions of organization members. Jap (2001) summarized prior findings and indicated that the attainment of joint competitive advantages can be achieved through specialized investments of buyers and suppliers. Crook and Combs (2007) revealed that collaborative supply chain management creates benefits for all supply chain members, particularly for the strong members. Lepak et al. (2007) revealed that when value is created by different parties, such as individual, organization, and society, value capture is dependent on the particular source that is related to the level of competition and isolating mechanisms when the value is created. Lindgreen et al. (2012) reviewed the value literature and showed that bundling activities enable value creation through integrating the available resources and thus managers can create development solutions and innovations and generate shared value. However, all the aforementioned papers didn't focus on the online to offline (O2O) competition of manufacturer – retail supply chain, particularly given the consideration of product compatibility to the web.

2.2. *Coordination mechanisms in the O2O distributions*

The operation of manufacturer - retailer supply chain, comprised of the O2O channels, has been studied in literature only recent decades. Levary and Mathieu (2000) showed that the O2O distributions hold most promise for the future. Rosenbloom (2007) illustrated that while O2O distributions has a major potential in the B2B market, managers have to create synergies across O2O channels and deal with channel conflict to coordinate O2O distributions. Yan and Ghose (2010) revealed that forecast precision has a different effect on the performances of both O2O retailers. All the aforementioned papers, however, didn't address how coordinative mechanisms can be utilized to coordinate the O2O distributions and improve supply chain performance.

When the manufacturer utilizes O2O channels to distribute its products, channel competition and conflict becomes a serious issue. Hence, coordinative mechanisms become an imperative tool to be utilized to coordinate the O2O distributions and solve the issue of channel conflict. Various coordinative mechanisms have been employed to reduce/eliminate the channel conflict. Without considering the price as a decision variable, Tsay and Agrawal (2004) illustrated that the invested sales efforts in the O2O channels can be used to coordinate the O2O distributions and help improve the supply chain performance when the identical product is to be sold through the O2O channels. Cattani et al. (2006) proposed an equal-pricing strategy for the O2O channels to mitigate the channel competition. Mukhopadhyay et al. (2008) proposed that the retailer can add additional value to product sold through the offline, thereby differentiating it from the basic product sold online. Cai (2010) showed that the revenue-sharing can be used to improve the supplier-retailer the performances when the supplier operates an online channel to compete the retailer. Amrouche and Yan (2016) demonstrated that the whole-channel price and quantity discount can be utilized to coordinate the O2O distributions in the manufacturer, online retailer, and traditional retailer supply chain. All the aforementioned papers, however, didn't consider the importance of reward points involved in a manufacturer's usage of O2O distributions. Furthermore, the aforementioned papers didn't consider the important factor of product web-compatibility in the O2O distributions. When a firm sells its product through online, product web-compatibility does play an important role for online sales (Kwak et al., 2002; Korgaonkar et al., 2006; Kumar and Ruan, 2006; Kacen et al., 2013). In addition, the aforementioned papers also didn't consider the important condition where the wholesale price charged from the manufacturer shouldn't be higher than the online price. If the charged wholesale price is higher than the online price, the retailer wouldn't buy from the manufacturer but buy from online channel directly or other arbitrators with a lower price.

Some papers do consider the factor of the product web-compatibility and the limit of wholesale price (which shouldn't be higher than the online price) in the O2O distributions. For example, Yan (2011) showed that the combination of brand differentiation with profit split can be utilized to improve the O2O distributions. Pei and Yan et al. (2015) found that supportive retail services can help achieve a Pareto result for both the manufacturer and the retailer in the O2O distributions. Yan et al. (2016) revealed that cooperative advertising combined with information sharing can be employed to coordinate O2O distributions conditionally in the manufacturer – retailer supply chain. All the aforementioned papers, however, didn't address the strategic role the reward points play in the O2O distributions and coordination, while our research examines this.

In addition, the aforementioned papers considered brand differentiation, cooperative advertising, information sharing, and retail services as coordinative mechanisms to alleviate the O2O competition and help improve supply chain performance, while our research proposes a novel and different coordinative mechanism (i.e. the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing) to solve the issue of O2O conflict and create a win-win result for both the manufacturer and the retailer when the manufacturer uses the O2O channels to distribute its products.

2.3. *Reward programs*

A substantial research studies the reward programs through consumer behaviors in the extant literature. For example, Bolton et al. (2000) examined the value of loyalty programs to company and found that loyalty reward program overlooks or discounts the negative evaluations about the company and thus helps improve consumers' retentions. Yi and Jeon (2003) examined how a loyalty reward program influences consumer's loyalty and showed that consumer's involvement plays an important role in moderating the relationship of loyalty reward program and consumer's loyalty. Lewis (2004) investigated the effect of loyalty program on consumers' purchases and illustrated that loyalty programs help increase the annual purchasing from the substantial proportion of consumers. Cao et al. (2010) proposed a comprehensive topology framework for researchers and practitioners to classify the various loyalty reward programs (LRP) and to study their differences and influences in the business operations, which provide a platform for future study on the design and implementation of loyalty reward programs. Melnyk and Van Osselaer (2012) implemented three experiments and a field study and found that the reward loyalty programs affect female and male consumers' responses to loyalty programs differently. In addition, some studies use empirical data to investigate the use of reward points programs as sales promotion strategy in the business market. For example, Dorotic et al. (2011) studied the own and cross-vendor effects of rewards on the sales of each vendor and revealed that the sales performance through the responsiveness of cardholders to LP (loyalty program)-induced promotions can be improved by using the multi-vendor loyalty promotions. Zhang and Breugelmans (2012) examined how the reward points programs can be utilized as retail sales promotion to stimulate consumers to buy in the item-based loyalty program. Their results showed that reward point promotions help reduce attrition among existing customers and attract more new customers. Wei and Xiao (2015) studied the impact of reward promotions in one category on other categories and found that reward promotions positively impact non-promoted but close-related category. Our research, however, is significantly different from the aforementioned studies: First, the aforementioned studies don't address reward programs through analytical modeling; instead they examine reward programs through consumer behaviors and empirical data analysis. Second, the aforementioned studies don't address the strategic value of reward points in the O2O competition of manufacturer - retailer supply chain. Third, the aforementioned studies don't consider the important factor of product compatibility to the web and its vital impact on the reward points. Finally, the aforementioned studies don't address the strategic value of the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing in the O2O competition of manufacturer – retailer supply chain. However, our research addresses these important issues.

Pei et al. (2018) recently studied the information sharing about the consumers' redemption rate on earned reward points in the O2O competition of manufacturer – retailer supply chain in their working paper. They showed that when the manufacturer offers the retailer a two-part tariff contract, the retailer would like to share its private information with the manufacturer only under certain condition; however, when the manufacturer offers the retailer a RPM (retail price maintenance) contract, the retailer has a strong self-motivation to share its private information with the manufacturer since RPM contract creates a win-win situation for all parties. Furthermore, the RPM contract also has a competitive advantage to help both the manufacturer and the retailer achieve higher profits and this competitive advantage would further increases as the product is more compatible with online sales. However, there are several major differences between our research and theirs: 1) Pei et al. (2018) consider information asymmetry about consumers' redemption rate on earned reward points and the strategic importance of information sharing, while our research doesn't consider any information asymmetry. 2) Pei et al. (2018) address how the two-part tariff and RPM contracts can be utilized to implement information sharing arrangement about the consumers' redemption rate on earned reward points, while our research considers how the manufacturer's financial support in reward points to the retailer and the profit sharing can be employed to mitigate the O2O competition. 3) Pei et al. (2018) focus on if the manufacturer and the retailer should implement an information sharing about consumers' redemption rate on earned reward points and what contract can be utilized to implement such an information sharing arrangement effectively and how the information accuracy impacts the value of RPM contract. However, our research focuses on how the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing coordinates the O2O distributions effectively and improves supply chain performance. Furthermore, different from Pei et al. (2018), our research also compares different modes to show if the Stackelberg mode or the simultaneous model can provide the manufacturer and the retailer a competitive advantage to benefit more when this combination strategy is implemented.

In the business market, although many retailers are using online store to sell their products to consumers, the online price is set to be equal to the offline physical store price in order to eliminate the issue of channel competition and conflict (Zhang, 2009). Furthermore, many retailers (e.g. Wal-Mart, Target, BestBuy, etc.) also are executing a price-match policy to ensure that the identical product is charged for an equal price in the O2O stores. Hence, in order to simplify the expression and eliminate any confusion, we define the retailer's channel distribution, which includes the O2O stores, as one simple term – offline channel - in this paper.

3. Model framework

In this section, we study a supply chain where the manufacturer sells a product directly through online to consumers and also sells the identical product to the offline retailer. We employ a Stackelberg game to analyze the supply chain. Cotterill and Putsis (2000) empirically revealed that the Stackelberg game does reflect a strategic interaction between the manufacturer and the retailer. Before we present our model development, we first present the notations used in the models, as summarized in Table 1.

******Insert Table 1 Here ******

3.1. Model development

When consumers buy online, we consider an important parameter g ($g > 0$) in our model. The parameter g is defined as the product web-compatibility, which is the extent synergy between the characteristics of a product and the Internet. Prior research (e.g. Chiang et al., 2003; Yan and Pei, 2015) shows that when the same product is bought through online, consumer's consumption value (i.e. an amount consumer is willing to pay) about this product would be less than the identical product bought through an offline channel. The Nielson Global Online Survey (2010) shows that online sales for different products are listed as: books (44%), clothing/accessories (36%), electronic equipment (27%), tours/hotel reservations (26%), cosmetics/nutrition supplies (22%), event tickets (20%), groceries (18%), music (16%), sporting goods (13%), computer software (11%), toys/dolls (11%), automobile parts (7%), baby supplies (7%), sport memorabilia (5%), and car hire (4%). Kacen et al. (2013) provide further evidence that many products' web-compatibilities, based on empirical data analysis, turn out to be less than one.

When consumers buy product from online, they would have a less consumption value about the product than the identical product bought from an offline channel. There are several reasons for this. First, many of the product attributes that are transparent to a consumer in an offline physical store, such as the fit of a pair of pants, are hidden in online. Even if consumers can check the products in the offline store before purchasing the identical products from online, product uncertainty cannot be completely eliminated. For example, when purchasing shoes of the same size, there can be some minor differences in the construction and fit of the shoes. When consumers buy online, this uncertainty always exists. However, when consumers buy from offline, this uncertainty can be eliminated by trying on the shoes in the offline store. Second, when consumers buy online, typically they need to wait several days for delivery and will be charged a shipping and handling fee. However, when consumers buy from the offline store, they can receive products immediately and the gratification is instant. Third, when consumers make a mistaken purchase and return products to online store, the refund is typically only partial (e.g. consumers need to pay the return shipping fee, restock fee for electronics) and also needs time to be processed, therefore leading to less consumption value. Fourth, post-purchase services may be reduced since online seller is located at a distance. Convenient services cannot be obtained. We consider these elements of online marketing and incorporate them into a simple model of consumer choice for product web-compatibility. In the first part of this paper, our model is developed for these products with the value of product web-compatibility in the interval of $0 < g < 1$. Then we study some products (e.g. digital music, airline tickets) which have an overwhelming advantage to be sold online over the offline environment (i.e. $g > 1$).

3.2. Scenario 1: O2O model (Benchmark model)

Suppose the product is sold through online at price p_1 and through offline at price p_2. Therefore, the consumer surplus through offline would be $v - p_2$. v is denoted as the consumer's consumption value (i.e. an amount consumer is willing to pay) when this product is bought from offline, and for analytic simplicity, it is assumed to be uniformly distributed from 0 to 1, with a density of 1. When this product is bought from online, its consumption value would be less than *v*. We capture the decrease in value by the parameter g. Hence, the consumption value of this product when bought through online would be gv, and the resulting consumer surplus is $gv - p_1$.

When consumers buy from offline, all consumers whose consumer surplus through offline is positive (i.e. $v - p_2 \geq 0$) will consider buying through offline. The marginal consumer whose consumption value v^r equals p_2 is indifferent to buying from offline. Similarly, all consumers whose consumer surplus through online is positive (i.e. $gv - p_1 \geq 0$) would consider buying online. The marginal consumer whose consumption value v^d equals p_1 / g is indifferent to buying online. Since consumers can buy from either online or offline, they would prefer the channel where they can derive more surplus. Thus, consumers will compare the consumer surplus derived through online with the consumer surplus derived through offline (i.e. $gv - p_1$ versus $v - p_2$) when they make decision to buy. For example, when a consumer can buy a Dell personal computer from either the offline retailer, Staples, or directly from Dell's online website, www.dell.com, he will compare the derived surplus to determine from which channel to buy. If $v - p_2 \geq gv - p_1$, then offline would be preferred to online. If $v - p_2 \leq gv - p_1$, then consumer would like to buy from online. The marginal consumer would be one who is indifferent between the online and offline channels and whose consumption value v^{dr} equals $(p_2 - p_1)/(1-g)$. Furthermore, it can be shown that when $v^d \leq v^r$, then $v^d \leq v^r \leq v^{dr}$. Hence, all consumers with consumption value in the interval $[v^d, v^{dr}]$ prefer to buy from online, and all those in the interval $[v^{dr}, 1]$ prefer to buy from offline. Consumers whose consumption values are found in $[0, v^d]$ won't buy product from either online or offline. Finally, all those consumers whose consumption values are in the interval $[v^r, 1]$ would buy from offline. Chiang et al. (2003) used a similar model structure. Let Q_1 and Q_2 denote the demands of online and offline, respectively, we then have

$$Q_1 = \frac{p_2 - p_1}{1-g} - \frac{p_1}{g} \tag{1}$$

$$Q_2 = 1 - \frac{p_2 - p_1}{1-g} \tag{2}$$

When $v^d \geq v^r$, then $v^d \geq v^r \geq v^{dr}$. Thus none of the consumers will buy from online but all consumers would buy from offline. Let d_o and d_r denote the demands of online and offline, respectively, we then have

$$d_r = 1 - p_2 \tag{3}$$

$$d_0 = 0 \tag{4}$$

We here focus on co-existing O2O distributions. Thus the demand functions (1) and (2) are our focus in this paper. Furthermore, as in Yan et al. (2016), we also assume a zero cost for both the manufacturer and the retailer to simplify the computations and expressions without losing the generality. Hence, when the manufacturer opens an online channel to compete with its offline retailer, the manufacturer's profit function can be written as

$$M = p_1 Q_1 + w Q_2 \tag{5}$$

The retailer's profit function can be written as

$$R = (p_2 - w)Q_2 \tag{6}$$

The mmanufacturer chooses online price p_1 and wholesale price w first to maximize its profit. In response to p_1 and w, the retailer updates a retail price p_2 to maximize its retail profit. To keep the retailer from buying from online or other arbitrators with a lower price, the wholesale price w shouldn't be higher than the online price p_1 (i.e. $p_1 \geq w$). Given the above structure, we obtain the optimal prices and profits in Table 2.

******Insert Table 2 Here ******

3.3. Scenario 2: O2O model with the manufacturer's financial support in reward points to the retailer

When the manufacturer opens an online channel to compete with the retailer, the manufacturer also provides a financial support to the retailer to implement a reward points program to help improve the retailer demand in order to alleviate the O2O competition. The offered financial support for reward points for unit product is defined as r. As a result, the demands of both the online and offline channels will be influenced by the effectiveness of reward points. While the reward points help increase consumers' benefits and stimulate consumers to buy from the retailer, the offered reward points in offline also take away some sales from online. When the product is less compatible with online sales, more consumers would like to buy from offline and thus more sales can be taken away from online. Hence, behaving as one of promotion strategies, the reward points program is assumed to have a linear relationship with the demand as in Yan and Pei (2015). Let D_1 and D_2 denote online and offline demands with the consideration of reward points, respectively, we then have

$$D_1 = Q_1 - (1-g)kr = \frac{p_2 - p_1}{1-g} - \frac{p_1}{g} - (1-g)kr \tag{7}$$

$$D_2 = Q_2 + kr = 1 - \frac{p_2 - p_1}{1-g} + kr \tag{8}$$

The parameter k ($0 < k < 1$) measures the effect of reward points on offline sales. The larger the value of k, the more efficient the reward points in stimulating (taking away) offline (online) sales.

While the reward points contribute to the demand increase, they also bring the cost due to the redemption of reward points. Wei and Xiao (2015) show that greater monetary rate converted from reward points (e.g. 6 reward points which can be converted into \$0.20 have a higher monetary rate than the same reward points which can be converted into \$0.10) would lead to higher redemption. Hence, the total number of consumers who would like to redeem the earned reward points can be modeled as

$$q = br \tag{9}$$

where, q is the total number of consumers who would like to redeem the earned reward points, and b is the redemption rate with respect to r. The value of b is in the interval ($0, k$) because not all consumers would redeem their earned reward points (Dorotic et al., 2011; Zhang and Breugelmans, 2012; Wei and Xiao, 2015).

As a result, when the manufacturer opens an online channel to compete with its retailer and provides financial support in reward points to the retailer, the profit functions of the manufacturer and the retailer can be written as

$$M^R = w(1 - \frac{p_2 - p_1}{1-g} + kr) + p_1(\frac{p_2 - p_1}{1-g} - \frac{p_1}{g} - (1-g)kr) - qr \tag{10}$$

$$R^R = (p_2 - w)(1 - \frac{p_2 - p_1}{1-g} + kr) \tag{11}$$

where, w is the manufacturer's whole price, M^R and R^R denote the manufacturer's profit and the retailer's profit, respectively, when the manufacturer provides financial support in reward points to the retailer. The moves of the manufacturer and the retailer follow a

Stackelberg game. Hence, in order to maximize their respective profits, the manufacturer moves first to set its wholesale price w, online price p_1, and the financial support in reward points r, and then the retailer sets its retail price p_2 accordingly. Furthermore, the charged wholesale price w shouldn't be higher than the online price p_1 (i.e. $p_1 \geq w$). Otherwise, the retailer wouldn't buy from the manufacturer but buy from online or other arbitrators with a lower price. Given the above structure, we summarize the equilibrium results in Table 3. Proofs are given in Appendix A.

******Insert Table 3 Here******

When the manufacturer opens an online channel to compete with its offline retailer and the manufacturer provides financial support in reward points to the retailer to alleviate the O2O competition, we examine how the product web-compatibility influences the manufacturer's financial support in reward points to the retailer. Based on our results, we obtain the proposition as follows. Proofs are given in Appendix B.

Proposition 1: *When the manufacturer opens an online channel to compete with its retailer and provides financial support in reward points to the offline retailer, the manufacturer's financial support in reward points would increase with the product web-compatibility.*

Proposition 1 shows that when the manufacturer opens an online channel to sell its product directly to consumers and provides financial support to the retailer to implement the reward points program, the product web-compatibility significantly influences the manufacturer's financial support in reward points. When a product becomes increasingly compatible with online sales, the manufacturer needs to provide more financial support n reward points to the retailer to stimulate the consumers' purchases. The rationale is that when the product becomes more compatible with online sales, more consumers would like to buy from online. Thus channel competition between the O2O becomes more intense. As a result, more financial support in reward points needs to be provided to the retailer to alleviate the channel competition. For example, digital products, books, and magazines have a strong compatibility with online sales and are the frequently purchased products from online. When the manufacturer opens an online channel to sell these products directly to consumers and leads to an O2O competition, the manufacturer does need to provide more financial support in reward points to the retailer to stimulate the offline sales and mitigate the O2O competition.

3.4. Comparing Scenario 2 and Scenario 1

Next, we present below a comparison of profits to investigate if it is beneficial for the manufacturer to provide financial support to the retailer to implement a reward points program. We thus compare the profits of both the manufacturer and the retailer in Table 3 with their profits in Table 2 and obtain the corresponding proposition as follows. Proofs are given in Appendix C.

Proposition 2: *When the manufacturer opens an online channel to compete with its retailer and provides financial support to the retailer to implement a reward points program, the manufacturer's profit increases with the product web-compatibility and the manufacturer also benefits from its financial support in reward points to the retailer; however, although the retailer's profit decreases with the product web-compatibility, the retailer does profit from the manufacturer's financial support in reward points to the retailer.*

Proposition 2 shows that when the manufacturer opens an online channel to compete with its retailer and provides financial support in reward points to the retailer, the provided reward points effectively improve the offline demand, which thus leads to higher profit to the retailer. However, when the product is more compatible with online sales, more consumers would buy from online, which thus brings less profit increase to the retailer. To the manufacturer, although the reward points take away some consumers from online, the profit increase due to increased demand from offline is greater than the profit decrease due to the decreased demand from online. Thus the manufacturer also profits from the financial support to the retailer to implement a reward points program. Particularly when the product is more compatible with online sales, more financial support would be provided to the retailer to implement the reward points program and thus leads to higher offline demand, which contributes higher profit to the manufacturer.

3.5. Scenario 3: O2O model with profit sharing

Here we propose that the manufacturer can utilize the profit sharing as an effective mechanism to coordinate the O2O distributions and thus a Pareto result can be achieved. Prior research (e.g. Belleflamme and Peitz, 2010; Blair and Lafontaine, 2015) shows that profit sharing effectively coordinates the franchisor – franchisee supply chain. However, it has not been explored in the extant literature if it can be utilized as an effective mechanism to coordinate O2O distributions in the manufacturer – retailer supply chain with the consideration of product web-compatibility.

When profit sharing is implemented between the manufacturer and the retailer, the retailer pays the manufacturer a wholesale price for each unit bought plus a percentage of the profit that the retailer generates. As a result, the profit functions with profit sharing can be written as follows:

$$M^s = w(1-\frac{p_2-p_1}{1-g}) + p_1(\frac{p_2-p_1}{1-g}-\frac{p_1}{g}) + t(p_2-w)(1-\frac{p_2-p_1}{1-g}) \quad (12)$$

$$R^s = (1-t)(p_2-w)(1-\frac{p_2-p_1}{1-g}) \quad (13)$$

where, M^s and R^s are the manufacturer's profit and the retailer's profit, respectively, in the profit sharing scenario. The parameter $t\,(0<t<1)$ represents the proportion of the retailer's profit that the supply chain players agree to share. Based on our analysis, we summarize the equilibrium results in Table 4. Proofs are given in Appendix D.

******Insert Table 4 Here******

3.6. Comparing Scenario 3 and Scenario 1

Next, we examine how profit sharing influences the profits of both the manufacturer and the retailer through comparing the profits of both the manufacturer and the retailer in Table 4 with their profits in Table 2. Based on our analysis, we obtain the corresponding pproposition as follows. Proofs are given in Appendix E.

Proposition 3: *While using profit sharing to coordinate the O2O distributions, the manufacturer always benefits from the profit sharing but the retailer doesn't benefit from the profit sharing, and the whole supply chain is indifferent to the profit sharing.*

Proposition 3 reveals that when the manufacturer uses online channel to sell product directly to consumers and utilizes profit sharing to coordinate the O2O distributions, profit sharing is beneficial to the manufacturer but not beneficial to the retailer. Furthermore, the performance of whole supply chain is not impacted by the profit sharing. Thus, a win-win opportunity cannot be achieved for both the manufacturer and the retailer through employing profit sharing as a mechanism to coordinate the O2O distributions. The rationale is that the increased profit for the manufacturer can't offset the retailer's lost profit due to profit sharing. Hence, the manufacturer isn't able to induce the retailer to implement a profit sharing to coordinate the O2O distributions.

In general, comparing to profit sharing mechanism, the manufacturer's financial support in reward points to the retailer does help improve the performance of whole supply chain and make a win-win result for both the manufacturer and the retailer. Thus this is a valuable and effective coordinative approach to be employed to coordinate the O2O distributions. However, the important question is if there is another valuable and effective mechanism which can be utilized to coordinate the O2O distributions and further improve the profits of both the whole supply chain and each supply chain player. Thus both the manufacturer and the retailer can achieve higher profits while they are employing such a mechanism to coordinate the O2O distributions.

3.7. Scenario 4: O2O model with the combination mechanism

Here we propose and investigate if the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing (i.e. the combination mechanism) can behave such a valuable and effective mechanism for the manufacturer and the retailer to employ in order to coordinate the O2O distributions. In other words, while the manufacturer is providing financial support to the retailer to implement a reward points program, the profit sharing between the manufacturer and the retailer also is implemented. Given the above structure, the profit functions with the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing can be written as follows:

$$M^{c} = w(1-\frac{p_2 - p_1}{1-g} + kr) + p_1(\frac{p_2 - p_1}{1-g} - \frac{p_1}{g} - (1-g)kr) + t(p_2 - w)(1-\frac{p_2 - p_1}{1-g} + kr) \quad (14)$$

$$R^{c} = (1-t)(p_2 - w)(1-\frac{p_2 - p_1}{1-g} + kr) \quad (15)$$

where, M^c and R^c are the manufacturer's profit and the retailer's profit, respectively, in the combination mechanism scenario. The parameter $t\,(0 < t < 1)$ represents the proportion of the retailer's profit that the supply chain players agree to share. Based on our analysis, we summarize the equilibrium results in Table 5. Proofs are given in Appendix F.

******Insert Table 5 Here******

3.8. Comparing Scenario 4 and Scenario 1

In order to explain the effect of the combined mechanism on the performances of supply chain players, we study how this mechanism impacts the profits of whole supply chain and all supply chain players. Therefore, it is critical to find under which mechanism both the manufacturer and the retailer can derive more profits. By comparing the profits of both the manufacturer and the retailer in Table 5 with their profits in Table 2, respectively, we can conclude only if the individual profit realized in the O2O distributions with the combination mechanism is higher than its profit in the O2O distributions without any coordinative mechanism, would both the manufacturer and the retailer like to implement such a combination mechanism. Otherwise, it is not in the interest of supply chain players to implement such a coordinative mechanism. Based on our results, we have the proposition as follows. Proofs are given in Appendix G.

Proposition 4: *When the manufacturer opens online channel to compete with its retailer and utilizes the combination of the manufacturer's financial support in reward points to* *the retailer with the profit sharing as coordinative mechanism, the manufacturer benefits from such a combination mechanism but the retailer doesn't. However, the whole supply chain profit does benefit from such a combination mechanism.*

Proposition 4 reveals some valuable findings. First, proposition 4 shows that when the manufacturer opens online channel to compete with its offline retailer and utilizes the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing as coordinative mechanism, the combination mechanism is beneficial to the manufacturer but not beneficial to the retailer. However, proposition 4 also reveals that the combination mechanism is beneficial to the whole supply chain. Thus, a win-win opportunity can be created for both the manufacturer and the retailer through employing the combination mechanism to coordinate the O2O distributions. The rationale is that the increased profit for the manufacturer can offset the decreased profit for the retailer due to employing the combination mechanism. Hence, the manufacturer is able to motivate the retailer to implement the combination mechanism through employing another coordinative mechanism - profit split. Profit split mechanism proposed by Amrouche and Yan (2015) can be employed to cooperatively split the increased profit generated by the combination coordination mechanism. As a result, a Pareto result can be achieved for both the manufacturer and the retailer.

3.9. Comparing Scenario 4 and Scenario 2

Since both the manufacturer's financial support in reward points to the retailer and the combined mechanism can be utilized as effective coordinative approaches to alleviate the O2O competition and help improve the performances of whole supply chain and each supply chain player, the important question is which mechanism has a competitive advantage to help both the manufacturer and the retailer achieve a higher performance individually. In order to answer this question, we compare the profits of both the manufacturer and the retailer in Table 5 with their respective profits in Table 3. Based on the comparison, we obtain the proposition as follows. Proofs are given in Appendix H.

Proposition 5: *When the manufacturer opens online channel to compete with its retailer* **(a)** *the manufacturer's profit with combination mechanism (i.e. the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing) is higher than its profit with the manufacturer's financial support in reward points to the retailer only,* **(b)** *but the retailers profit with combination mechanism is lower than its profit with the manufacturer's financial support in reward points to the retailer only; however,* **(c)** *the whole supply chain profit with the combination mechanism is higher than its profit with the manufacturer's financial support in reward points to the retailer only.*

Proposition 5 shows some important and new findings when the profits of both the manufacturer and the retailer in the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing is compared with their profits with the manufacturer's financial support in reward points to the retailer only. To the manufacturer, it benefits from the profit sharing and the increased demand due to its financial support to the retailer to implement the reward points program. To the retailer, it wouldn't benefit from the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing. The rationale is that the profit decrease due to profit sharing is larger than the profit increase due to the manufacturer's financial support in reward points, which thus leads to less profit.

However, proposition 4(c) shows that the whole supply chain's profit in the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing is higher than its profit with the manufacturer's financial support in reward points to the retailer only, which is an important new finding. The reason is that the manufacturer's financial support in reward points to the retailer helps improve the profit of whole supply chain but the profit sharing mechanism doesn't, thus it is logic to reasoning that the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing shouldn't be better than the manufacturer's financial support in reward points to the retailer to help improve the profit of whole supply chain. However, multiple cooperative behaviors do coordinate the whole supply chain better and thus generate higher profit for the whole supply chain, which in turn would bring higher profits to both the manufacturer and the retailer. Thus the manufacturer and the retailer can utilize profit split mechanism, which is proposed by Amrouche and Yan (2015), to split the increased profit (due to implementing the combination mechanism) and create a Pareto result for both the manufacturer and the retailer. Therefore, comparing to the manufacturer's financial support in reward points to the retailer, the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing is a more valuable and effective coordination mechanism to be employed by supply chain players to coordinate the O2O distributions in the manufacturer – retailer supply chain.

3.10. Numerical examples

The purpose of our numerical examples is to illustrate the value of the combination mechanism (i.e. the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing) in the O2O distributions of manufacturer – retailer supply chain. The numerical examples will justify the comparisons of different scenarios, complement our analytical results, and provide us with more managerial insights. The values we used for the various parameters in our numerical examples are shown in Table 6. We vary the value of product web-compatibility to find its effect on the performance of the manufacturer, the retailer, and the whole supply chain under different scenarios.

********Insert Table 6 Here********

********Insert Figs. 1, 2, and 3 Here********

Figs. 1 and 2 show that when the manufacturer's financial support in reward points is offered to the retailer, the manufacturer's profit increases with the product web-compatibility but the retailer's profit decreases with the product web-compatibility and both the manufacturer and the retailer achieve higher profits than they behave in the O2O benchmark model. These results justify the comparison of scenario 2 with scenario 1. Furthermore, Figs. 1, 2, and 3 also demonstrate that when the combination mechanism is employed to coordinate the O2O distributions, the manufacturer's profit is higher than its profit with O2O benchmark model but the retailer's profit is lower than its profit with O2O benchmark model; however, the whole supply chain profit is higher than its profit with O2O benchmark model. These results justify the comparison of scenario 4 with scenario 1.

Next, Figs. 1 and 2 show that the manufacturer's profit with combination mechanism is higher than its profit with the manufacturer's financial support in reward points to the retailer only but the retailers profit with combination mechanism is lower than its profit with the manufacturer's financial support in reward points to the retailer only. However, Fig. 3 illustrates that the whole supply chain profit with the combination mechanism is higher than its profit with the manufacturer's financial support in reward points to the retailer only, which can create a win-win opportunity for both the manufacturer and the retailer through profit split mechanism. These results justify the comparison of scenario 4 with scenario 2.

In general, the combination mechanism has a competitive advantage to help improve the profits of both the manufacturer and the retailer and thus is a more valuable strategy for the supply chain players to employ than the manufacturer's financial support in reward points to the retailer only. However, the competitive advantage of combination mechanism (the profit difference between the combination mechanism and the manufacturer's financial support in reward points to the retailer) decreases for the whole supply chain as the product web-compatibility increases. The rationale is that as the product becomes increasingly compatible with online sales, O2O competition increases. As a result, the coordinative power of combination mechanism decreases for the whole supply chain. Thus the business managers need to pay attention to the product sold through the O2O channels, since the product web-compatibility significantly impacts the competitive advantage of combination mechanism. In other words, when the product has a weak compatibility with online sales, the combination mechanism has a larger competitive advantage than the manufacturer's financial support in reward points to the retailer; when the product has a strong compatibility with online sales, the competitive advantage of combination mechanism would decrease.

4. Simultaneous mode

Analytical modeling scholars have showed that the qualitative insights regarding optimal business strategy often rely on the assumed mode of conduct in the business market (Moorthy, 1993). Hence, one form of mode conduct could have a better advantage than the other in alleviating price competition (Serwer, 1994). We here assume that the manufacturer and the retailer play a simultaneous mode. In the simultaneous mode, both the manufacturer and the retailer make decisions independently of one another with a goal to maximizing their own profits. In other words, the manufacturer determines its wholesale and online prices and support in reward points to maximize its profit and the retailer sets its retail price to maximize its profit simultaneously. Our interest in this research is to examine which mode (Stackelberg mode or simultaneous mode) has a competitive advantage to be employed when the manufacturer uses the combination mechanism to coordinate the O2O distributions. Given the above structure, we obtain the equilibrium results in Table 7. Proofs are given in Appendix I.

******Insert Table 7 Here******

Further, in order to study the effect of different modes (Stackelberg mode or simultaneous mode) on supply chain performance, we need to find under which mode both the manufacturer and the retailer can derive more profits. By comparing the profits of both the manufacturer and the retailer in Table 7 with their profits in Table 5, we can conclude if the individual profit realized in the Stackelberg mode is higher than that obtained in the simultaneous mode, both the manufacturer and the retailer would like to employ this mode in their businesses. If the individual profit realized in the Stackelberg mode is equal to that obtained in the simultaneous mode, both the manufacturer and the retailer can employ either the Stackelberg mode or simultaneous mode to maximize their profits. Based on our results, we have the proposition as follows. Proofs are given in Appendix J.

Proposition 6: *The profits of both the manufacturer and the retailer in the Stackelberg mode are the same as their respective profits in the simultaneous mode, when the manufacturer and the retailer use the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing mechanism to coordinate the O2O distributions.*

Proposition 6 indicates an important and novel result. Our result shows that the profits of both the manufacturer and the retailer in the Stackelberg mode are equal to their respective profits in the simultaneous mode, when the manufacturer and the retailer uses the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing mechanism to coordinate the O2O distributions. However, this result is contrary to prior studies (e.g. Raju and Roy, 2000; Yue and Liu, 2006) which show that the Stackelberg mode is more coordinated than a simultaneous mode and always leads to higher profits to supply chain players. The rationale is that inclusion of the product web-compatibility into the analytical model changes the results of prior studies. However, Raju and Roy (2000) and Yue and Liu (2006) didn't consider the important role the product web-compatibility plays on the online channel. In the business market, product web-compatibility does influence online sales significantly (Kwak et al., 2002; Korgaonkar et al., 2006; Kumar and Ruan, 2006; Kacen et al., 2013). Our consideration about the important role of the product web-compatibility does reflect real business situation in practice and make our findings interesting for business managers doing business in the O2O distributions of manufacturer – retailer supply chain.

5. Product web-compatibility is larger than one ($g > 1$)

Following the similar model development in section 3.2, we have the demand functions as follows:

$$d_1 = \frac{p_1 - p_2}{g-1} - \frac{p_1}{g} \quad (16)$$

$$d_2 = 1 - \frac{p_1 - p_2}{g-1} \quad (17)$$

where, d_1 and d_2 denote the demands of the online and traditional channels, respectively. As a result, the manufacturer's profit is given as

$$M = p_1 d_1 + w d_2 \quad (18)$$

The retailer' profit is given as

$$R = (p_2 - w) d_2 \quad (19)$$

Given the above structure, we have our results summarized in Table 8.

******Insert Table 8 Here******

The results in Table 8 show that when a product has an overwhelming advantage to be sold online over the offline, the offline retailer will disappear but the online sales will become much more popular. For example, many offline air-ticket agents disappeared and online air-ticket sales become popular in the business market. As a result, either the combination mechanism or the manufacturer's financial support in reward points to the retailer wouldn't work in this case.

6. Conclusions and managerial implications

6.1. *Implications for research*

Nowadays e-commerce is becoming more and more popular in the business market, many manufacturers thus would like to open their online channels to sell product directly to consumers, which leads to channel competition between the manufacturer and the retailer since retail partners are concerned that the orders placed through a manufacturer's online channel might reduce their own sales. As a result, the important questions is that when the manufacturer opens an online channel to compete with its retailer, what effective coordination mechanism can be utilized to alleviate the O2O competition and conflict and help improve the performances of all supply chain players? Previous studies show that sales efforts (Tsay and Agrawal, 2004), information sharing (Yue and Liu, 2006), brand differentiation between O2O channels (Yan, 2011), the added retail services (Mukhopadhyay et al., 2008), cooperative advertising (Yan et al., 2016) can be employed to mitigate the O2O competition in the manufacturer – retailer supply chain. However, different from previous studies, our research addresses this important question by proposing a valuable mechanism, which is never addressed in the extant literature, for business managers to employ and studying its strategic value in the O2O distributions of manufacturer – retailer supply chain.

Specifically, we first develop some valuable models and then make game theoretical analysis to show that when product is less compatible with online sales than with offline sales, the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing is a valuable coordination mechanism to be utilized to alleviate the channel conflict and help improve supply chain performance in the O2O distributions. Furthermore, we also show that the profits of both the manufacturer and the retailer in the Stackelberg mode are the same as their respective profits in the simultaneous mode. As a result, when the manufacturer opens an online channel to implement O2O distributions, it can employ either a Stackelberg or simulate nous mode to provide financial support to the retailer to implement a reward points program and implement profit sharing with the retailer simultaneously and thus a Pareto result can be achieved for all supply chain players. However, if product enjoys an overwhelming advantage to be sold online, it is not in the interest of the manufacturer to employ the combination coordination mechanism or provide financial support in reward points to the retailer.

In general, our research studies the strategic effects of both the combination of the manufacturer's financial support in reward points to the retailer with the profit sharing and the mode choice on the performances of both the manufacturer and the retailer when the manufacturer sells its products through O2O distributions. Our results show that employing such a combination mechanism through adopting either a Stackelberg or simultaneous mode is a win-win strategy for supply chain players to employ. The wise investments and mode choice would effectively alleviate the O2O competition and help improve the performances of all supply chain players. Consequently, both the manufacturer and the retailer would value this strategy very much.

6.2. *Implications for business managers*

Our research addresses important issues and our findings provide valuable managerial implications to business managers in the O2O distributions of manufacturer-retailer supply chain. The most significant contribution is that our paper contributes to the substantial and growing research on the value of coordination mechanism by initiating an innovative mechanism for the supply chain players to employ, when the manufacturer utilizes O2O channels to distribute its products. With the rapid development of technology, many manufacturers would like to add an online channel to their traditional distribution systems to engage in O2O distributions, which leads to serious channel competition and conflict. O2O coordination has become a hot topic in supply chain management. Hence, it is managerially important to develop some valuable coordination mechanisms to improve channel coordination and supply chain performance when the opened online channel is to compete with the offline retailer. In this research, through game theoretical models, we are able to develop some novel and effective coordinative mechanism for the supply chain players to employ. We have identified the values of both the combination of the manufacturer's support in reward points to the retailer with the profit sharing mechanism and the appropriate mode structure that play an important role in formulating the policies of both the manufacturer and the retailer. We have also established condition under which the O2O distributions would be more profitable for both the manufacturer and the retailer. In fact, valuable coordination mechanism, particularly innovative coordination approach (e.g. the combination of the manufacturer's support in reward points to the retailer with the profit sharing) would be recommended as important means for the business managers to employ in order to improve channel coordination as well as to increase the profits of both the manufacturer and the retailer. As a result, even if the manufacturer needs to bear the costs for providing financial support in reward points to the retailer and share the increased profit, the combination mechanism still is a mandatory and highly valuable approach to be utilized to alleviate the O2O competition and help all supply chain players achieve higher profits in the O2O distributions.

In sum, our research shows that there appears to be definite benefits to all supply chain players that effectively master a combination mechanism in the O2O distributions. The combination mechanism reflects a competitive capability that, when implemented correctly, is always a double-winning proposition for all supply chain players. From a practical standpoint, our analysis provides important insights that help supply chain players identify the values of both the combination mechanism and the appropriate mode structure and make optimal decisions. Business managers in the real business are able to use the managerial insights derived from our research to make smart investments to improve their decision-makings and profits. For instance, the manufacturer and its retailer can choose to play either a Stackelberg or simultaneous mode and employ the combination of the manufacturer's support in reward points to the retailer with the profit sharing as the coordination mechanism, thus a win-win situation can be reached when the manufacturer sells its product through the O2O distributions. Furthermore, both the manufacturer and the retailer also need to study the factor of product compatibility to the web very carefully when the manufacturer plans to open an online channel, since this factor significantly influences their investments and thus returns.

This research has a limitation of be just theoretical and there is no empirical examination. However, our research does develop valuable models for business managers to employ through considering important parameters, such as product web-compatibility, consumer's redemption rate on eared reward points, the profit sharing rate, and so forth. All of these parameters are testable in the empirical examinations. For example, data about web-compatibility of products such as computers, digital products, shoes, toothpastes, and so forth, are available in the business market and can be collected through market research as Kacen et al. (2013) did. Furthermore, reward points programs are popular in the business market and the retailers always have the data about the redemption rate of earned reward points. In addition, profit sharing mechanism has attracted substantial attention in the supply chain management and has been practiced in various industries, such as beer, gasoline, car and apparel, and so forth (Blair and Lafontaine, 2015). Thus empirical researchers can collect the data to test our analytical models and investigate whether the qualitative implications derived in our analytical models can be generalized to empirical models.

Table 1. Summary of notations in the models

Notation	Interpretation
v	The consumer's consumption value about this product in the offline channel
gv	The consumer's consumption value about this product in the online channel
v^r	Marginal consumer's consumption value about this product for buying from offline
v^d	Marginal consumer's consumption value about this product for buying from online
v^{dr}	Marginal consumer's consumption value about this product between the online and offline channels
g	Product web-compatibility
p_1	Price in the online channel
p_2	Price in the offline channel
w	The wholesale price charged from the manufacturer
r^i ($i = R, c, B$)	The offered reward points under different scenarios
q	The total number of consumers who would like to redeem the earned reward points
k	The effect of reward points on offline sales
b	The redemption rate of reward points
M and M^i ($i = R, s, c, B$)	The manufacturer's profit under different scenarios
R and R^i ($i = R, s, c, B$)	The retailer's profit under different scenarios

Table 2. Equilibrium results in the O2O benchmark model

Wholesale price, w	$\frac{g}{2}$
Online price, p_1	$\frac{g}{2}$
Offline price, p_2	$\frac{1}{2}$
Manufacturer's profit, M	$\frac{g}{4}$
Retailer's profit, R	$\frac{1-g}{4}$

Table 3. Equilibrium results in the O2O model with the manufacturer's financial support in reward points to the retailer

Wholesale price, w^R	$\frac{2gb}{4b-g^3k^2}$
Online price, p_1^R	$\frac{2gb}{4b-g^3k^2}$
Offline price, p_2^R	$\frac{4b+(1-g)^2g^2k^2}{8b-2g^3k^2}$
Reward points, r^R	$\frac{g^2k}{4b-g^3k^2}$
Manufacturer's profit, M^R	$\frac{b(4bg+(1-2g)g^3k^2)}{(4b-g^3k^2)^2}$
Retailer's profit, R^R	$\frac{(1-g)(4b+(1-g)g^2k^2)^2}{4(4b-g^3k^2)^2}$

where, $4b-g^3k^2>0$

Table 4. Equilibrium results in the O2O model with profit sharing

Wholesale price, w^s	$\frac{g}{2}$
Online price, p_1^s	$\frac{g}{2}$
Offline price, p_2^s	$\frac{1}{2}$
Manufacturer's profit, M^s	$\frac{g+t-gt}{4}$
Retailer's profit, R^s	$\frac{(1-g)(1-t)}{4}$

Table 5. Equilibrium results in the O2O model with combination mechanism

Wholesale price, w^c	$\frac{g(4b-(1-g)^2k^2t)}{8b-2k^2(g^3+t-gt)}$
Online price, p_1^c	$\frac{g(4b-(1-g)^2k^2t)}{8b-2k^2(g^3+t-gt)}$
Offline price, p_2^c	$\frac{4b+(1-g)^2gk^2(g-t)}{8b-2k^2(g^3+t-gt)}$
Reward points, r^c	$\frac{k(g^2+t-gt)}{4b-k^2(g^3+t-gt)}$
Manufacturer's profit, M^c	$\frac{(1+kr)((1-g)(1+kr)t-2w)-4br^2}{4}$
Retailer's profit, R^c	$\frac{(1-g)(1-t)(4b+(1-g)g^2k^2)^2}{4(4b-k^2(g^3+t-gt))^2}$

where, $4b-k^2(g^3+t-gt)>0$

Table 6. Parameters values and range of values used in the numerical examples

Parameters	Base values and range of values
g	0-0.99
b	0.6
k	0.7
t	0.4

Table 7. Equilibrium results in the O2O model with combination mechanism in the simultaneous mode

Wholesale price, w^B	$\frac{g(4b-(1-g)^2k^2t)}{8b-2k^2(g^3+t-gt)}$
Online price, p_1^B	$\frac{g(4b-(1-g)^2k^2t)}{8b-2k^2(g^3+t-gt)}$
Offline price, p_2^B	$\frac{4b+(1-g)^2gk^2(g-t)}{8b-2k^2(g^3+t-gt)}$
Reward points, r^B	$\frac{k(g^2+t-gt)}{4b-k^2(g^3+t-gt)}$
Manufacturer's profit, M^B	$\frac{(1+kr)((1-g)(1+kr)t-2w)-4br^2}{4}$
Retailer's profit, R^B	$\frac{(1-g)(1-t)(4b+(1-g)g^2k^2)^2}{4(4b-k^2(g^3+t-gt))^2}$

where, $4b-k^2(g^3+t-gt)>0$

Table 8. Equilibrium results in the O2O model with $g>1$

Wholesale price, w	$\frac{1}{2}$
Online price, p_1	$\frac{g}{2}$
Offline price, p_2	$\frac{3-g}{4}$
Manufacturer's profit, M	$\frac{g}{8}$
Retailer's profit, R	0

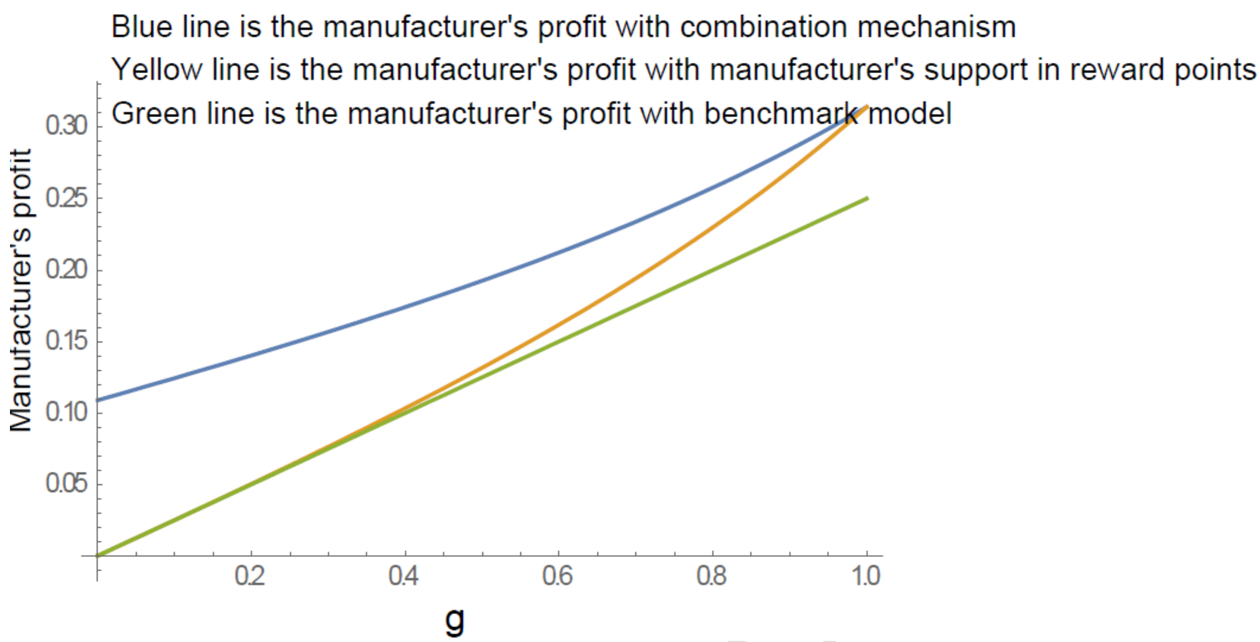

Fig. 1. The effect of product web-compatibility on manufacturer's profit under different scenarios

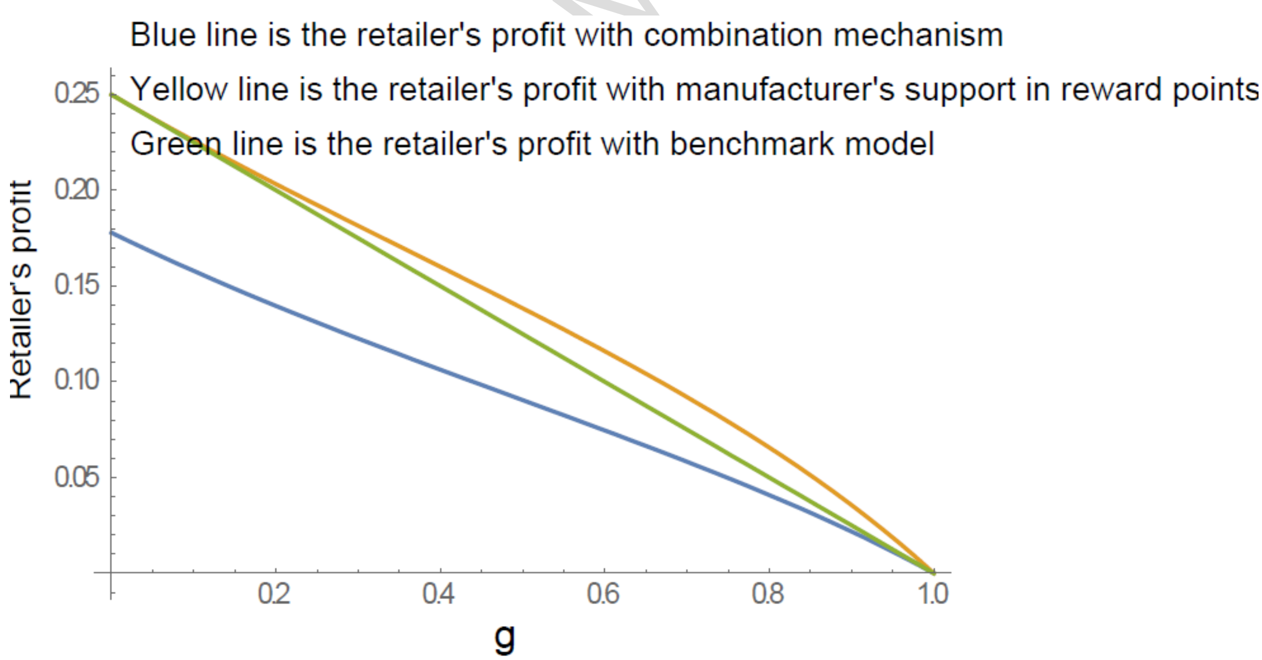

Fig. 2. The effect of product web-compatibility on retailer's profit under different scenarios

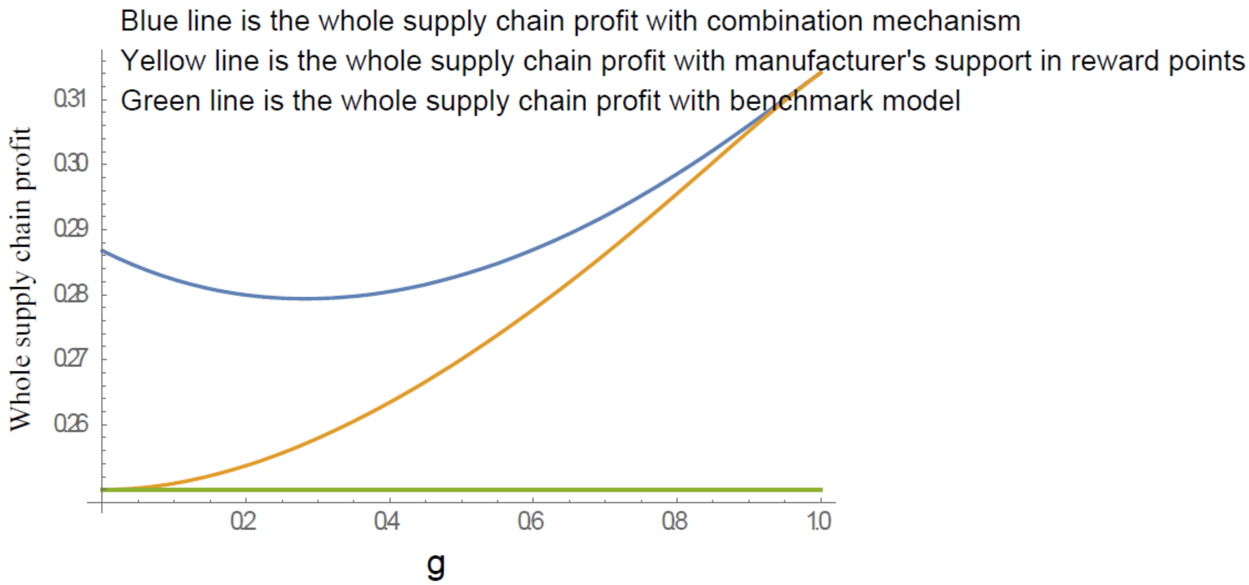

Fig. 3. The effect of product web-compatibility on whole supply chain profit under different scenarios

Appendix A

$$D_1 = Q_1 - (1-g)kr = \frac{p_2 - p_1}{1-g} - \frac{p_1}{g} - (1-g)kr$$

$$D_2 = Q_2 + kr = 1 - \frac{p_2 - p_1}{1-g} + kr$$

$$q = br$$

The profit function for the manufacturer is given as

$$M^R = w(1 - \frac{p_2 - p_1}{1-g} + kr) + p_1(\frac{p_2 - p_1}{1-g} - \frac{p_1}{g} - (1-g)kr) - qr$$

The profit function for the retailer is given as

$$R^R = (p_2 - w)(1 - \frac{p_2 - p_1}{1-g} + kr)$$

We first need to find if the retailer's profit function has a concave relationship with its retail price p_2, thus an optimal p_2 exists for the retailer. As a result, we obtain $\frac{\partial R^R}{\partial p_2^2} = -\frac{2}{1-g} < 0$. Thus we prove that there is a concave relationship between the retailer's profit function and its retail price. Therefore, we find the retailer's price through letting $\frac{\partial R^R}{\partial p_2} = 0$, then we obtain $p_2 = \frac{1 + p_1 + kr - g(1+kr) + w}{2}$.

Next, substituting the value of p_2 into

$M^R = w(1 - \frac{p_2 - p_1}{1-g} + kr) + p_1(\frac{p_2 - p_1}{1-g} - \frac{p_1}{g} - (1-g)kr) - qr$ and then we need to find if the manufacturer's profit function has a concave relationship with its wholesale price w, online price p_1, and offered reward points r, respectively, thus optimal w, p_1, and r exist for the manufacturer. Since there are three decision variables in the manufacturer's profit function, the Hassian matrix for the manufacturer's profit function is stated as

$\begin{bmatrix} fxx & fxy & fxz \\ fyx & fyy & fyz \\ fzx & fzy & fzz \end{bmatrix}$. Thus we have $\begin{bmatrix} -\frac{1}{1-g} & \frac{1}{1-g} & \frac{k}{2} \\ \frac{1}{1-g} & -\frac{2-g}{g(1-g)} & k(g-\frac{1}{2}) \\ \frac{k}{2} & k(g-\frac{1}{2}) & -2b \end{bmatrix}$

Since $H_1 = fxx < 0$, $H_2 = \begin{bmatrix} fxx & fxy \\ fyx & fyz \end{bmatrix} > 0$, and $H_3 = \begin{bmatrix} fxx & fxy & fxz \\ fyx & fyy & fyz \\ fzx & fzy & fzz \end{bmatrix} < 0$ under the condition of $4b - g^3k^2 > 0$, the manufacturer's profit function is strictly concave with its decision variables and has unique maxima. In other words, equilibrium exists for optimal wholesale price, online price, and offered reward points. Thus we prove that there is a concave relationship between the manufacturer's profit function and its wholesale price, online price, and offered reward points, respectively. Hence, letting $\frac{\partial M^R}{\partial p_1} = 0$, $\frac{\partial M^R}{\partial w} = 0$, and $\frac{\partial M^R}{\partial r} = 0$ with the consideration of $p_1 \geq w$, then we obtain $w = \frac{2bg}{4b - g^3 k^2}$,

$p_1 = \frac{2bg}{4b - g^3 k^2}$, and $r = \frac{g^2 k}{4b - g^3 k^2}$

After submitting the above results into the profit functions of the manufacturer and the retailer with the condition of $D_i \geq 0$ ($i = 1,2$), we obtain all the results summarized in Table 3. Furthermore, we also check if the demand validness condition is satisfied. Through checking our analysis, our results show that the demand condition is satisfied.

Appendix B

Because $r = \frac{g^2 k}{4b - g^3 k^2}$, we then obtain $\partial r / \partial g = \frac{8bgk + g^4 k^3}{(4b - g^3 k^2)^2} > 0$

Thus, Proposition 1 is proved.

Appendix C

When the manufacturer opens an online channel and provides financial support in reward points to the retailer, the profits of the manufacturer and the retailer are given as

$M^R = \frac{b(4bg + (1-2g)g^3 k^2)}{(4b - g^3 k^2)^2}$ and $R^R = \frac{(1-g)(4b + (1-g)g^2 k^2)^2}{4(4b - g^3 k^2)^2}$

We then obtain $\partial M^R / \partial g = \frac{b(16b^2 + 12b(1-g)g^2 k^2 + (3-4g)g^5 k^4)}{(4b - g^3 k^2)^2} > 0$; similarly we can obtain $\partial R^R / \partial g < 0$.

When the manufacturer opens an online channel but there is no coordinative mechanism, the profits are given as

$M = \frac{g}{4}$ and $R = \frac{1-g}{4}$

Through comparing M^R with M, we obtain $M^R - M = \frac{g^3 k^2 (4b - g^4 k^2)}{4(4b - g^3 k^2)^2} > 0$. Similarly, we can obtain $R^R - R = \frac{(1-g)(2g^2(4b - g^3 k^2) + g^4 k^4)}{4(4b - g^3 k^2)^2} > 0$.

Thus, Proposition 2 is proved.

Appendix D

When the manufacturer and the retailer implement the profit sharing in the O2O distributions, the profit functions are given as

$$M^s = w(1 - \frac{p_2 - p_1}{1-g}) + p_1(\frac{p_2 - p_1}{1-g} - \frac{p_1}{g}) + t(p_2 - w)(1 - \frac{p_2 - p_1}{1-g})$$

$$R^s = (1-t)(p_2 - w)(1 - \frac{p_2 - p_1}{1-g})$$

Following the same proofs as in Appendix 1, we can prove that the profit functions of both the manufacturer and the retailer are strictly concave with their decision variables and optimal values exist for both the manufacturer and the retailer. Therefore, given the retailer's profit function, we find the optimal retailer's retail price as

$$p_2 = \frac{1 - g + w + p_1}{2}$$

Substituting p_2 into the manufacturer's profit function and taking the derivative of M^s on p_1 and w, respectively, given the condition of $p_1 \geq w$, we obtain

$$w = \frac{g}{2},\ p_1 = \frac{g}{2}, \text{ and } p_2 = \frac{1}{2}$$

Then we submit the results into the profit functions of the manufacturer and the retailer, we thus obtain all the results summarized in Table 4. Furthermore, we also check if the demand validness condition is satisfied. Through checking our analysis, our results show that the demand condition is satisfied.

Appendix E

When the manufacturer opens an online channel and implement the profit sharing with the retailer, the profits of the manufacturer and the retailer are given as

$$M^s = \frac{g + t - gt}{4} \text{ and } R^s = \frac{(1-g)(1-t)}{4}$$

When the manufacturer opens an online channel but there is no coordinative mechanism, the profits of the manufacturer and the retailer are given as

$$M = \frac{g}{4} \text{ and } R = \frac{1-g}{4}$$

Through comparing M^s with M, we obtain $M^s - M = \frac{t(1-g)}{4} > 0$. Similarly, we can obtain $R^s - R = -\frac{(1-g)t}{4} < 0$, and $M^s + R^s - M - R = 0$

Thus, Proposition 3 is proved.

Appendix F

When the manufacturer provides financial support in reward points to the retailer and in the meantime, implements a profit sharing arrangement with the retailer, the profit functions are given as

$$M^c = w(1 - \frac{p_2 - p_1}{1-g} + kr) + p_1(\frac{p_2 - p_1}{1-g} - \frac{p_1}{g} - (1-g)kr) + t(p_2 - w)(1 - \frac{p_2 - p_1}{1-g} + kr)$$

$$R^c = (1-t)(p_2 - w)(1 - \frac{p_2 - p_1}{1-g} + kr)$$

Following the same proofs as in Appendix 1, we obtain $\frac{\partial R^c}{\partial p_2^2} = -\frac{2(1-t)}{1-g} < 0$. Thus we prove that there is a concave relationship between the retailer's profit function and its retail price. Therefore, we find the retailer's price through letting $\frac{\partial R^R}{\partial p_2} = 0$, then we obtain $p_2 = \frac{1 + p_1 + kr - g(1+kr) + w}{2}$. Further, substituting the value of p_2 into

$$M^c = w(1 - \frac{p_2 - p_1}{1-g} + kr) + p_1(\frac{p_2 - p_1}{1-g} - \frac{p_1}{g} - (1-g)kr) + t(p_2 - w)(1 - \frac{p_2 - p_1}{1-g} + kr)$$

Since the Hassian matrix for the manufacturer's profit function is stated as

$\begin{bmatrix} fxx & fxy & fxz \\ fyx & fyy & fyz \\ fzx & fzy & fzz \end{bmatrix}$. Thus we have $\begin{bmatrix} -\frac{2-t}{2(1-g)} & \frac{2-t}{2(1-g)} & \frac{k(1-t)}{2} \\ \frac{2-t}{2(1-g)} & -\frac{4-g(2+t)}{2g(1-g)} & -\frac{k(1-2g-t)}{2} \\ \frac{k(1-t)}{2} & -\frac{k(1-2g-t)}{2} & -\frac{4b-(1-g)k^2 t}{2} \end{bmatrix}$

Since $H_1 = fxx < 0$, $H_2 = \begin{bmatrix} fxx & fxy \\ fyx & fyz \end{bmatrix} > 0$, and $H_3 = \begin{bmatrix} fxx & fxy & fxz \\ fyx & fyy & fyz \\ fzx & fzy & fzz \end{bmatrix} < 0$ under the condition of $4b - k^2(g^3 + t - gt) > 0$, the manufacturer's profit function is strictly concave with its decision variables and has unique maxima. In other words, equilibrium does exist for optimal wholesale price, online price, and offered reward points. Thus we prove that there is a concave relationship between the manufacturer's profit function and its wholesale price, online price, and offered reward points, respectively. Hence, letting $\frac{\partial M^c}{\partial p_1} = 0$, $\frac{\partial M^c}{\partial w} = 0$, and $\frac{\partial M^c}{\partial r} = 0$ with the consideration of $p_1 \geq w$, then we find the manufacturer's wholesale and online prices, offered reward points, and optimal retailer's retail price as

$$w = \frac{g(4b-(1-g)^2k^2t)}{8b-2k^2(g^3+t-gt)}, p_1 = \frac{g(4b-(1-g)^2k^2t)}{8b-2k^2(g^3+t-gt)}, \text{and } r = \frac{k(g^2+t-gt)}{4b-k^2(g^3+t-gt)}$$

Then we submit the results into the profit functions of the manufacturer and the retailer with the condition of $D_i \geq 0$ ($i = 1,2$), we thus obtain all the results summarized in Table 5. Furthermore, we also check if the demand validness condition is satisfied. Through checking our analysis, our results show that the demand condition is satisfied.

Appendix G

When the manufacturer opens an online channel and implement the profit sharing with the retailer, the profits of the manufacturer and the retailer are given as

$$M^c = \frac{(1+kr)((1-g)(1+kr)t-2w)-4br^2}{4}, \; w = \frac{g(4b-(1-g)^2k^2t)}{8b-2k^2(g^3+t-gt)},$$

$$r = \frac{k(g^2+t-gt)}{4b-k^2(g^3+t-gt)} \text{ and } R^c = \frac{(1-g)(1-t)(4b+(1-g)g^2k^2)^2}{4(4b-k^2(g^3+t-gt))^2}$$

When the manufacturer opens an online channel but there is no coordination mechanism, the profits of the manufacturer and the retailer are given as

$$M = \frac{g}{4} \text{ and } R = \frac{1-g}{4}$$

Through comparing M^c with M, after some computations, we obtain $M^c - M > 0$.

Similarly, we can obtain $R^c - R < 0$, and $M^c + R^c - M - R > 0$

Thus, Proposition 4 is proved.

Appendix H

When the manufacturer opens an online channel and implement the profit sharing with the retailer, the profits of the manufacturer and the retailer are given as

$$M^c = \frac{(1+kr)((1-g)(1+kr)t-2w)-4br^2}{4},\ w = \frac{g(4b-(1-g)^2k^2t)}{8b-2k^2(g^3+t-gt)},$$

$$r = \frac{k(g^2+t-gt)}{4b-k^2(g^3+t-gt)} \text{ and } R^c = \frac{(1-g)(1-t)(4b+(1-g)g^2k^2)^2}{4(4b-k^2(g^3+t-gt))^2}$$

When the manufacturer opens an online channel and provides financial support in reward points to the retailer, the profits of the manufacturer and the retailer are given as

$$M^R = \frac{b(4bg+(1-2g)g^3k^2)}{(4b-g^3k^2)^2} \text{ and } R^R = \frac{(1-g)(4b+(1-g)g^2k^2)^2}{4(4b-g^3k^2)^2}$$

Through comparing M^c with M^R, after some computations, we obtain $M^c - M^R > 0$.

Similarly, we can obtain $R^c - R^R < 0$, and $M^c + R^c - M^R - R^R > 0$

Thus, Proposition 5 is proved.

Appendix I

When the manufacturer and the retailer implement the combination strategy to behave independently to make their own decisions simultaneously, the profit functions are given as

$$M^B = w(1-\frac{p_2-p_1}{1-g}+kr)+p_1(\frac{p_2-p_1}{1-g}-\frac{p_1}{g}-(1-g)kr)+t(p_2-w)(1-\frac{p_2-p_1}{1-g}+kr)$$

$$R^B = (1-t)(p_2-w)(1-\frac{p_2-p_1}{1-g}+kr)$$

Following the same proofs as in Appendix 6, we can prove that the profit functions of both the manufacturer and the retailer are strictly concave and have unique maxima. In other words, equilibrium does exist in the simultaneous mode. When the manufacturer and the retailer play a simultaneous mode, they make decisions simultaneously with the condition of $p_1 \geq w$, we thus obtain

$$w = \frac{g(4b-(1-g)^2 k^2 t)}{8b - 2k^2(g^3 + t - gt)},\ p_1 = \frac{g(4b-(1-g)^2 k^2 t)}{8b - 2k^2(g^3 + t - gt)},\ r = \frac{k(g^2 + t - gt)}{4b - k^2(g^3 + t - gt)},$$

and $p_2 = \dfrac{4b + (1-g)^2 g k^2 (g-t)}{8b - 2k^2(g^3 + t - gt)}$

Then we submit the above results into the profit functions of the manufacturer and the retailer and consider the condition of $D_i \geq 0$ ($i = 1,2$), we obtain all the results summarized in Table 7. Furthermore, we also check if the demand validness condition is satisfied. Through checking our analysis, our results show that the demand condition is satisfied.

Appendix J

Through comparing M^c with M^B , after some computations, we obtain $M^c - M^B = 0$. Similarly, we obtain $R^c - R^B = 0$. Thus, Proposition 6 is proved.

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