Dual-channel closed-loop supply chain with government consumption-subsidy

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**Abstract**

The government has been acting as an important role in the formation and operation of closed-loop supply chain. This paper focuses on how consumption-subsidy influences dual-channel closed-loop supply chain. After introducing government consumption-subsidy program and dual-channel closed-loop supply chain, the paper analyzes the channel members’ decisions before and after the government-funded program performance, respectively. Finally, influence of consumption-subsidy has been considered from the consumers, the scale of closed-loop supply chain and the enterprises perspectives, which provides an important basis for our propositions. The key propositions of the paper are listed as follows: All the consumers that purchase the new products are beneficiaries of the government consumption-subsidy in varying degrees; the consumption-subsidy is conducive to the expansion of closed-loop supply chain; both the manufacturer and the retailer are beneficiaries of the consumption-subsidy, while the e-tailer benefits or not is uncertain.

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1. Introduction

In recent years, the economic and environmental benefits of recovering obsolete products have been widely recognized in literature and practice. Closed-loop supply chain can generate profits by taking back products from consumers and recovering the remaining added value (Guide and Van Wassenhove, 2001; Savaskan et al., 2004; Ferguson and Toktay, 2006; Geyer et al., 2007; Schluep et al., 2009). Thierry et al. (1995) offered a system model of closed-loop supply chain, and divided the product recovery into five options: repair, refurbishing, remanufacturing, cannibalization, and recycling. Depending on the economics of a particular situation, recovery process may reuse the entire product, selected modules, components, and/or parts (Atasu et al., 2008).

Guide and Van Wassenhove (2009) introduced the field of closed-loop supply chains with a strong business perspective. However, obsolete products (especially electronic wastes) can cause environmental damage if not dealt with in appropriate ways (Chi et al., 2011). Atasu et al. (2009) discussed the economic and environmental impacts of extended producer responsibility type of legislation and identified efficiency conditions.

In China, the government has been acting as an important role in the formation and operation of closed-loop supply chain. In order to stimulate domestic consumption, curb pollution and develop circular economy, the government announced detailed subsidy plans for home appliance consumption and replacement: (1) on November 26, 2007, the Chinese government announced a government-funded program aiming to expand home appliance sales in rural areas. According to the policy, rural consumers would receive a consumption-subsidy worth 13% of the new appliance’s price (Ministry of Commerce of the People’s Republic of China, 2007) and (2) on June 1, 2009, the Chinese government announced the detailed subsidy plan for home appliance replacements. According to the policy, consumers will receive a replacement-subsidy worth 10% of the price of five kinds of new appliances—televisions, refrigerators, washing machines, air-conditioners and computers (China’s State Council General Office, 2009).

In this paper, we focus on how the consumption-subsidy influences the dual-channel closed-loop supply chain.

The internet has provided consumers a new way to interact with their supply chain. Electronic commerce has been widely hailed as a revolution to permanently transform the landscape of consumer/supplier relationships. For example, according to a research by China e-Business Research Center, China’s fast-growing e-commerce transactions hit 4.5 trillion yuan ($682.16 billion) in 2010, up 22% year-on-year. Of the 4.5 trillion yuan, online B2B (Business-to-Business) sector accounted for 3.8 trillion yuan ($576.05 billion), increasing by 15.8% year-on-year. The online retail business hit 513.1 billion yuan ($77.78 billion), a boost of 97.3% from the previous year (China e-Business Research Center, 2011).

Additionally, during the nascent period of electronic commerce, independent e-tailers played a dominant role in the development of internet-based sales to consumers. For many product categories, independent e-tailers continue to play a vital role in their industry’s supply chains. Hence, in this paper, we focus our attention on the dual-channel closed-loop supply chain, in which...
a manufacturer, a traditional retailer and an internet-based retailer each exist as independent entities.

This type of dual-channel with a traditional channel and an internet-based channel have been widely studied. Chiang et al. (2003) constructed a price-setting game between a manufacturer and its independent retailer and showed that the mere threat of introducing the direct channel can increase the manufacturers negotiated share of cooperative profits even if price efficiency is obtained by using other business practices. Cattani et al. (2004) focused on the coordination opportunities that arise when a firm participates in both a traditional channel and an internet channel. Chiang and Monahan (2005) indicated that the dual-channel strategy outperforms the other two channel strategies in most cases, and the cost reductions realized by the flexibility of the dual-channel system may be significant under some circumstances. Cattani et al. (2006) analyzed a scenario where a manufacturer with a traditional channel partner (i.e., a retailer) opens up a direct internet channel that is in competition with the traditional channel partner.

Although all members’ decisions and closed-loop supply chain’s indexes will be influenced by the subsidy, to simplify the analysis and to highlight the focus of our study, we only consider the manufacturer, the retailer and the e-tailer’s decisions, and discuss the subsidy influence from the consumers, the scale of closed-loop supply chain and the enterprises perspectives, respectively.

The remainder of the paper is organized as follows. The following section is devoted to the model conceptualization and formulation. Section 3 analyzes the channel decisions of closed-loop supply chain models before and after the government-funded program, respectively. Through comparing the corresponding results obtained in Section 3, we explain how the consumption-subsidy influences the dual-channel closed-loop supply chain in Section 4. Finally, conclusions are provided in the last section.

2. Model assumptions and notations

The goal of this paper is to develop an understanding of the influence of consumption-subsidy on the consumers, the scale of the closed-loop supply chain and the enterprises. To this end, we formulate a basic dual-channel closed-loop supply chain model (Model N, Fig. 1a), in which new products are produced by the manufacturer and sold by the retailer and the e-tailer. Based on this model, we formulate and analyze another closed-loop supply chain model (Model S, Fig. 1b), in which the consumers can receive consumption-subsidy.

In the rest of the paper, the following notations defined in Table 1 are used.

For the sake of simplicity, we consider the following scenario and make the following modeling assumptions.

Assumption 1. We consider closed-loop supply chains with only one kind of product. A family should own one and only one product, whether new or obsolete.

According to the policy in China, the government subsidizes the consumption of many kinds of home appliances, and there are different brands of each kind of home appliance. But for simplicity, we consider the closed-loop supply chain with a single kind of product. The last part of Assumption 1 tallies with the actual situation.

Assumption 2. The obsolete products are identical, and only used to be recycled.

Because of the rapid development of science and technology, home appliances are very easily outdated. In the real situation, most of obsolete home appliances can only be used for recycling, and their values are similar. So for simplicity, we consider the obsolete products as identical.

Assumption 3. While optimizing their objective functions, all closed-loop supply chain members have access to the same information. The manufacturer has sufficient channel power over the retailer and the e-tailer to act as a Stackelberg leader.

The former part of this assumption enables us to control inefficiencies and risk-sharing issues resulting from information asymmetry. The similar forms of this assumption have been widely used (Savaskan et al., 2004). The latter of this assumption states that the manufacturer uses his/her foresight about the retailer and the e-tailer’s reaction functions in her decision making.

![Fig. 1. Closed-loop supply chain models.](image-url)
Stackelberg structure for the solution of similar games has been widely used in the supply chain literature (Savaskan et al., 2004; Tayur et al., 1998).

**Assumption 4.** There are two types of consumers: primary consumers \((P)\) and replacement consumers \((R)\). The primary consumer does not have an obsolete product and can purchase a new product directly. The replacement consumer has an obsolete product and should sell his/her obsolete one when he/she purchases a new one. During a certain period, the market size is \(A\), and the ratio of the replacement consumer is \(\mu\).

**Assumption 5.** The primary and replacement consumers are heterogeneous with \(\delta^p\) and \(\delta^r\), respectively. And \(\delta^p\) and \(\delta^r\) are assumed to be uniformly distributed between 0 and 1.

The similar forms of the last part of this assumption have been widely used in the consumer segmentation (Chiang and Monahan, 2005; Debo et al., 2005; Atas et al., 2009). On the one hand, the consumers are willing to pay more for the retailer’s than the e-tailer’s products. On the other hand, the cost of selling a new product by retailer is more than the one by e-tailer \((c_r > c_e)\). These are the fundamental reasons why the dual-channel can be formed.

**Assumption 6.** The consumption-subsidy is related to the new product’s price. When purchasing the new product from the retailer, the consumer can get subsidy \(\varphi_p\), \(0 < \varphi < 1\). And when purchasing the new product from the e-tailer, the consumer can get subsidy \(\varphi_e\).

This assumption is merely for simplicity and comparison. From the above assumptions, we draw the following conclusions:

(1) In Model N, a primary consumer gets utility \(U^p = \theta^p - p_r\) and \(U^r = \delta p_r - p_e\) via purchasing a new product from the retailer and the e-tailer, respectively. Similarly, a replacement consumer gets utility \(U^r = \theta^r - p_r + p_e\) and \(U^e = \delta p_r - p_e\) via purchasing a new product from the retailer and the e-tailer, respectively.

(2) In Model S, a primary consumer gets utility \(U^p = \theta^p - p_r + \varphi_p p_r\) and \(U^e = \delta p_r - p_e + \varphi_p p_r\) via purchasing a new product from the retailer and the e-tailer, respectively. Similarly, a replacement consumer gets utility \(U^r = \theta^r - p_r + p_e + \varphi_p p_r\) and \(U^e = \delta p_r - p_e + p_e + \varphi_p p_r\) via purchasing a new product from the retailer and the e-tailer, respectively.

The primary consumer purchases a new product from the retailer if \(U^p > U^e\) and \(U^e > 0\), and purchases a new product from the e-tailer if \(U^p > U^e\) and \(U^e > 0\). The replacement consumer purchases a new product from the retailer if \(U^r > U^e\) and \(U^e > 0\), and purchases a new product from the e-tailer if \(U^r > U^e\) and \(U^e > 0\).

**Assumption 7.** \(\frac{p_r}{p_e} < \delta < 1 - p_r + p_e\).

In Model N, \(U^p - U^e = (1 - \delta)\theta^p - p_r + p_e\) and \(U^r - U^e = (1 - \delta)\theta^r - p_r + p_e\). The consumers with higher \(wtp\) (willingness to pay) perfect to purchase new product from the retailer. In order to ensure the existence of dual-channel closed-loop supply chain, the consumers whose \(wtp\) is 1 must purchase new product from the retailer, and the consumers whose \(wtp\) is \(\frac{p_r}{p_e}\) must purchase new product from the e-tailer. In other words, for the primary consumers, when \(\theta^p = 1\), \(U^p > U^e\) and \(U^e > 0\); when \(\theta^r = \frac{p_r}{p_e}\), \(U^r > U^e\) and \(U^e > 0\). Thus, \(\frac{p_r}{p_e} < \delta < 1 - p_r + p_e\).

Similarly, in Model S, \(U^p - U^e = (1 - \delta)\theta^p - (1 - \delta)(p_r - p_e)\) and \(U^r - U^e = (1 - \delta)\theta^r - (1 - \delta)(p_r - p_e)\). In order to ensure the existence of dual-channel closed-loop supply chain, the consumers whose \(wtp\) is 1 must purchase new product from the retailer, and the consumers whose \(wtp\) is \(\frac{p_r}{p_e}\) must purchase new product from the e-tailer. Thus, \(\frac{p_r}{p_e} < \delta < 1 - (1 - \theta)\). And when \(\theta^p = 1\), \(\frac{p_r}{p_e} < \delta < 1 - \theta\). When purchasing a new product from the e-tailer, \(\theta^r = 1\) and \(\frac{p_r}{p_e} < \delta < 1 - \theta\).

**Assumption 8.** The closed-loop supply chain decisions are considered in a single-period setting.

We assume the previous existence of the product in the market. Those products sold in the previous periods can be recycled. The similar forms of this assumption have been widely used (Savaskan et al., 2004).

### 3. Model formulation and solution

This section presents the manufacturer, the retailer and the e-tailer’s decisions in different models, respectively.

Before analyzing the game between the channel members, we must discuss the demand functions in the different models. According to the assumptions in the last section, we may conclude the following:

(1) In Model N, for the primary consumers whose \(wtp\) is in the interval \([\frac{p_r}{p_e} \div 1, 1]\), \(U^p > U^e\) and \(U^e > 0\); for the replacement consumers whose \(wtp\) is in the interval \([\frac{p_r}{p_e} \div 1, 1]\), \(U^r > U^e\) and \(U^e > 0\); for the primary consumers whose \(wtp\) is in the interval \([\frac{p_r}{p_e} \div \frac{p_r}{p_e} - \frac{p_r}{p_e}, 1]\), \(U^p > U^r\) and \(U^p > 0\); for the replacement consumers whose \(wtp\) is in the interval \([\frac{p_r}{p_e} \div \frac{p_r}{p_e} - \frac{p_r}{p_e}, 1]\), \(U^r > U^e\) and \(U^r > 0\);

\[
\begin{align*}
q^p &= \Delta(1 - \theta) \left[1 - \frac{p_r - p_e}{p_r - p_e}\right], \\
q^r &= \Delta \theta \left[1 - \frac{p_r - p_e}{p_r - p_e}\right].
\end{align*}
\]

(2) In Model S, for the primary consumers whose \(wtp\) is in the interval \([\frac{1 - \theta}{1 - \theta} \div 1, 1]\), \(U^p > U^e\) and \(U^e > 0\); for the replacement consumers whose \(wtp\) is in the interval \([\frac{1 - \theta}{1 - \theta} \div \frac{1 - \theta}{1 - \theta} - \frac{p_r}{p_e}, 1]\), \(U^r > U^e\) and \(U^r > 0\); for the replacement consumers whose \(wtp\) is in the interval \([\frac{1 - \theta}{1 - \theta} \div \frac{1 - \theta}{1 - \theta} - \frac{p_r}{p_e}, 1]\), \(U^e > U^e\) and \(U^e > 0\);

\[
\begin{align*}
q^p &= \Delta(1 - \theta) \left[1 - \frac{p_r - p_e}{p_r - p_e}\right], \\
q^r &= \Delta \theta \left[1 - \frac{p_r - p_e}{p_r - p_e}\right].
\end{align*}
\]

#### 3.1. Model N – no subsidy

A benchmark for describing how the consumption-subsidy influences the dual-channel closed-loop supply chain is provided by Model N.

Because the manufacturer is the Stackelberg leader, we begin by characterizing the best-response functions of the retailer and the e-tailer. For a given \(w\), the retailer and the e-tailer’s problems are

\[
\begin{align*}
\max_{p_r} \quad & P_r^N = q_r(p_r - w - c_r) - \frac{c_e}{\delta} \left(p_r - \frac{p_r}{p_e} - \frac{c_e}{\delta}\right) (p_r - w - c_e), \\
\max_{p_e} \quad & P_e^N = q_e(p_e - w - c_e) - \frac{p_r}{\delta} \left(p_r - \frac{p_r}{p_e} - \frac{c_e}{\delta}\right) (p_r - w - c_e).
\end{align*}
\]
From the concavity of the objective functions, we determine the best response functions from the first-order conditions for \( p_r \) and \( p_e \). Thus, one can easily show that

\[
p_{r}^{*} = \frac{1}{4 - \delta} \left[ \frac{2}{1 - \delta} + 3w + 2c_r + c_e + \beta(1 - \delta)p_e \right],
\]

\[
p_{e}^{*} = \frac{1}{4 - \delta} \left[ \frac{2}{1 - \delta} + (2 + \delta)w + \delta c_r + 2c_e + \beta(1 - \delta)p_e \right].
\]

Given the retailer and the e-tailer’s response functions, the manufacturer solves

\[
\max_{w} \Pi^N_m = q^*(w - c_m) = \alpha \left( 1 - \frac{p_{r}^{*} - \beta p_e^{*}}{\delta} \right)(w - c_m),
\]

to determine the new product’s wholesale price.

Because the objective function is concave in \( w \), one can easily show that the optimal new product’s wholesale price is given by

\[
w^* = \frac{1}{2(2 + \delta)} \left[ 3\delta + (2 + \delta)c_m - \delta c_r - 2c_e + \beta(2 + \delta)p_e \right].
\]

Optimal new product’s prices and equilibrium new product sales, quantity of the obsolete product recycling and channel profits can easily be found by substitution of \( w^* \). To improve readability, the results are listed in Table 2 in Appendix A.

3.2. Model S – consumption-subsidy

In this model, the consumers will receive a unit subsidy when he/she replaces his/her product. Just as in Model N, for a given \( w \), the retailer and the e-tailer solve

\[
\max_{p_r} \Pi^S_r = q_r(p_r - w - c_r) = \alpha \left( 1 - \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \right)(p_r - w - c_r),
\]

\[
\max_{p_e} \Pi^S_e = q_e(p_e - w - c_e) = \alpha \left( 1 - \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \right)(1 - \phi)p_e - \beta p_e^{*}
\]

\( (p_r - w - c_r) \).

Because the objective functions are concave in \( p_r \) and \( p_e \), respectively, the retailer and the e-tailer’s first-order conditions characterize the unique best response,

\[
p_{r}^{*} = \frac{1}{4 - \delta} \left[ \frac{2}{1 - \phi} + 3w + 2c_r + c_e + \beta(1 - \delta)p_e \right],
\]

\[
p_{e}^{*} = \frac{1}{4 - \delta} \left[ \frac{2}{1 - \phi} + (2 + \delta)w + \delta c_r + 2c_e + \beta(1 - \delta)p_e \right] - \frac{\beta p_e^{*}}{1 - \delta}.
\]

The manufacturer’s problem can be stated as:

\[
\max_{w} \Pi^S_m = q^*(w - c_m) = \alpha \left( 1 - \frac{1 - (1 - \phi)p_r^{*} - \beta p_e^{*}}{1 - \phi} \right)(w - c_m).
\]

Again, the objective function is concave in \( w \), and the manufacturer’s first-order condition characterizes the unique best response,

\[
w^* = \frac{3\delta}{2(2 + \delta)} \left[ \frac{1 - \phi}{1 - \delta} + (2 + \delta)c_m - \delta c_r - 2c_e + \beta(2 + \delta)p_e \right].
\]

Optimal new product’s prices and equilibrium new product sales, quantity of the obsolete product recycling and channel profits can easily be found by substitution of \( w^* \). The results are also listed in Table 2 in Appendix A.

4. Influence of consumption-subsidy

This section will focus on how consumption-subsidy influences the dual-channel closed-loop supply chain from the consumers, the scale of closed-loop supply chain and the enterprises perspectives, and reach a series of propositions. For the sake of comparison, we tag the superscript ‘*’ to the symbols under Model S, e.g. \( p_r^{*} \) denotes the unit price of a new product in the retailer under Model S.

4.1. Consumers perspective

Through analyzing the assumptions and the results in the preceding sections, we can generate the following results: In Model N, the consumers whose \( w_{tp} \) is in the interval [\( \frac{w_{tp}}{2}, 1 \)] purchase the new products from the retailer. The primary consumers whose \( w_{tp} \) is in the interval [\( \frac{w_{tp}}{2}, \frac{w_{tp}}{2} + \frac{1}{2} \)] purchase the new products from the e-tailer. Fig. 2 shows the retailer and the e-tailer’s sales under different models.

Because \( \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \) and the replacement consumers whose \( w_{tp} \) is in the interval [\( \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \)] purchase the new products from the retailer. The primary consumers whose \( w_{tp} \) is in the interval [\( \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \)] and the replacement consumers whose \( w_{tp} \) is in the interval [\( \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \)] purchase the new products from the e-tailer. Due to the government’s subsidy program, they will save \( \beta (p_r - p_e) \) and every primary consumer will save \( \beta (p_r - p_e) \).

(1) For the consumers whose \( w_{tp} \) is in the interval [\( \frac{w_{tp}}{2}, 1 \)], subsidies do not influence their choices. They purchase the new products from the retailer. And due to the government’s subsidy program, they will save \( p_r - (p_r - p_e) \). It is a fixed value and equals to \( \frac{\beta \delta}{4 - \delta} \).

(2) For the consumers whose \( w_{tp} \) is in the interval [\( \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \)], subsidies influence their choices. Due to the government’s subsidy program, they will no longer purchase the new products from the retailer, but to purchase the new products from the e-tailer. Every primary consumer will save \( [\beta (p_r - p_e) - \beta (p_r - p_e)] \), and every replacement consumer will save \( \beta (p_r - p_e) \).

(3) For the primary consumers whose \( w_{tp} \) is in the interval [\( \frac{w_{tp}}{2}, \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \)] and the replacement consumers whose \( w_{tp} \) is in the interval [\( \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \)], subsidies do not influence their choices. They will purchase the new products from the e-tailer. Due to the government’s subsidy program, they will save \( p_r - (p_r - p_e) \). It is a fixed value and equals to \( \beta \delta \).

(4) For the primary consumers whose \( w_{tp} \) is in the interval [\( \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \)] and the replacement consumers whose \( w_{tp} \) is in the interval [\( \frac{1 - (1 - \phi)(p_r - p_e)}{1 - \delta} \)], subsidies influence them obviously. Without the government’s subsidy program, they will not purchase any product. And with the government’s subsidy program, they will purchase the new products from the e-tailer. The primary and the replacement consumers can get utility \( \beta (p_r - p_e) \) and \( \beta (p_r - p_e) + p_r \) from their purchases, respectively.
Both the primary consumers whose $wtp$ is in the interval $\left[\frac{1 - \omega p_t}{p_r}, 1\right]$ and the replacement consumers whose $wtp$ is in the interval $\left[\frac{1 - \omega p_t}{p_t}, \frac{1}{2}\right]$ benefit from the subsidy. And who gets the most benefit? The red lines in Fig. 2 give us a visual presentation.

4.2. Scale of closed-loop supply chain

What is the scale of closed-loop supply chain? As we all know, the closed-loop supply chain consists of forward and reverse supply chains. In this paper, we use the sale of new products and the quantity of obsolete product recycling to represent the scales of the forward and reverse supply chains, respectively.

From the assumptions and the analysis in the above, we know that the replacement consumers whose $wtp$ is in the intervals $\left[\frac{1 - \omega p_t}{p_t}, \frac{1}{2}\right]$ and $\left[\frac{1 - \omega p_t}{p_t}, 1\right]$ purchase new products from the retailer or the e-tailer and sell their obsolete products to reverse supply chains under Model N and Model S, respectively. Through a simple comparison, we can draw that $q^e > q^r$. It means that subsidy augments the scales of reverse supply chain. The quantity of the obsolete product recycling equals to $q^r$ under Model N and Model S, respectively. $q^e$ is the sum of $q^e_1$ and $q^e_2$. $q^r$ is the sum of $q^r_1$ and $q^r_2$. In Fig. 2b, we will find the change easily.

Apart from replacement consumers, some primary consumers also buy new products. The primary consumers whose $wtp$ is in the intervals $\left[\frac{1 - \omega p_t}{p_t}, 0\right]$ and $\left[\frac{1 - \omega p_t}{p_t}, \frac{1}{2}\right]$ purchase the new products from the retailer or the e-tailer under Model N and Model S, respectively. Through a simple comparison, we can draw that $q^e > q^r$. $q^e$ is the sum of $q^e_1$ and $q^e_2$. $q^r$ is the sum of $q^r_1$ and $q^r_2$. It means that more new products are purchased by the primary consumers when the government subsidizes the consumption. Fig. 2a shows this change clearly.

The sales of the new product are $q$ and $q^e$ under Model N and Model S, respectively. $q$ is the sum of $q^e$ and $q^r$. $q^e$ is the sum of $q^e_1$ and $q^e_2$. $q^r$ and $q^r_2$. Thus, the subsidy augments the scale of the forward supply chains.

This subsection has clearly showed that the subsidy is conducive to the expansion of closed-loop supply chain.

4.3. Enterprises perspectives

This subsection focuses on how subsidy influences the enterprises. To simplify the analysis, we just consider a basic dual-channel closed-loop supply chain, and only consider the decisions of the manufacturer, the retailer and the e-tailer. The manufacturer makes profit from manufacturing and wholesaling new products to the retailer and the e-tailer, while the retailer and the e-tailer make profit from selling new products to primary and replacement consumers.

The manufacturer’s profit function ($\Pi_m = q(w - c_m)$) points out that profit not only relates to total sales, but also relates to wholesale price. From the above analysis, we know that subsidy stimulates consumers to purchase more products. Additionally, $w' := w = \frac{w}{1 - \omega p_t} + \beta(2 + \delta)p_s > 0$. Thus, we can draw a conclusion that the subsidy increases the manufacturer’s profit.

Similarly, the retailer’s profit function ($\Pi_r = q_r(p_r - w - c_1)$) points out that profit not only relates to sales by himself, but also relates to the new product’s price in retailer and wholesale price. From the above analysis, we know that no matter there is subsidy or not, the consumers whose $wtp$ is in the interval $\left[\frac{1 - \omega p_t}{p_r}, 1\right]$ purchase the new products from the retailer. And due to the government’s subsidy program, the consumers whose $wtp$ is in the interval $\left[\frac{1 - \omega p_t}{p_t}, \frac{1}{2}\right]$ are no longer to purchase new products from e-tailer, but to purchase new products from the retailer. Therefore, subsidy stimulates consumers to purchase more products from the retailer. Additionally, though the wholesale price increases after the government subsidizes consumption, new product’s price in the retailer increases more as $(p_r - w') - (p_r - w) = \frac{\omega(1 - \omega p_t) - \beta(2 + \delta)p_s}{2(1 - \omega p_t) - \beta(2 + \delta)p_s} > 0$. After the above analysis, we can draw a proposition that the retailer is a beneficiary of the government consumption-subsidy.
In this paper, we also consider the e-tailer’s decision, and how the consumption-subsidy influences the e-tailer. The e-tailer’s profit function \( P_e = q_e(p_e - w - c_e) \) points out that profit not only relates to sales by himself, but also relates to new product’s price in e-tailer and wholesale price. From the above analysis, we know that no matter there is subsidy or not, the consumers whose wtp is in the interval \( \frac{p_e - c_e}{q_e(\frac{p_e - c_e}{q_e} - \frac{1 - \phi(p_e - p_r)}{1 - \phi})} \) purchase new products from the e-tailer. The consumers whose wtp is in the interval \( \frac{1 - \phi(p_e - p_r)}{1 - \phi} \) are no longer to purchase new products from e-tailer, but to purchase new products from the retailer. The primary consumers whose wtp is in the interval \( \frac{1 - \phi(p_e - p_r)}{1 - \phi} \) and the replacement consumers whose wtp is in the interval \( \frac{1 - \phi(p_e - p_r)}{1 - \phi} \) purchase new products from the e-tailer only after the government subsidizes consumption. Whether sales by the e-tailer will increase or decrease is decided by the relationship between \( \frac{p_e - c_e}{q_e(\frac{p_e - c_e}{q_e} - \frac{1 - \phi(p_e - p_r)}{1 - \phi})} \) and \( \frac{w - p_e}{q_e} \). Additionally, both wholesale price and new product’s price increase after the government subsidizes consumption. Which one increases more? It is also an uncertain problem. Thus, it is an uncertain question that the e-tailer is winner or loser of the government subsidy program.

This section has focused on how the consumption-subsidy influences the dual-channel closed-loop supply chain from the consumers, the scale of closed-loop supply chain and the enterprises perspectives, respectively. Through analyzing a series of questions, we can come up with some propositions, such as changes of sales by the retailer and the e-tailer.

5. Conclusions

For different purposes, various countries have issued series of measures attempting to influence the closed-loop supply chain. This paper focuses on the consumption-subsidy.

In the early phase of this research, we have introduced the government consumption-subsidy program and explained the reason why we choose the dual-channel closed-loop supply chain, not the single-channel one as the research object. Based on the introduction and the explanation, we have made a number of assumptions to develop a more comprehensive understanding of different dual-channel closed-loop supply chain models. Then, a series of equilibrium channel indexes under different models have been worked out. Finally, from the consumers, the scale of closed-loop supply chain and the enterprises perspectives, we have considered the influences of the consumption-subsidy, respectively.

The key propositions of the paper are listed as follows: all the consumers that purchase the new products are beneficiaries of the government consumption-subsidy in varying degrees; the consumption-subsidy is conducive to the expansion of closed-loop supply chain; both the manufacturer and the retailer are beneficiaries of the consumption-subsidy, while the e-tailer benefits or not is uncertain.

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Appendix A

See Table 2.

References


