Managing channel profit and total surplus in a closed-loop supply chain network

Citation for published version:
Jena, SK, Ghadge, A & Sarmah, SP 2018, 'Managing channel profit and total surplus in a closed-loop supply chain network', *Journal of the Operational Research Society*, vol. 69, no. 9, pp. 1345-1356. https://doi.org/10.1080/01605682.2017.1392408

Digital Object Identifier (DOI):
10.1080/01605682.2017.1392408

Link:
Link to publication record in Heriot-Watt Research Portal

Document Version:
Peer reviewed version

Published In:
Journal of the Operational Research Society

Jena, S. Ghadge, A. and Sarmah, S. (2017), "*Managing channel profit and total surplus in a closed-loop supply chain network*", **Journal of Operations Research Society**, *forthcoming*.

Managing channel profit and total surplus in a closed-loop supply chain network

Abstract: Today's government is interested in the product recovery program in order to encourage sustainability. The research develops four closed-loop supply chain models by considering different scenarios for the governmental subsidies and fees under price sensitive demand. Analytical results suggest that the government should provide subsidies to both manufacturer and collector in order to maximize channel profit and total surplus. Higher subsidies advocates manufacturer's intention to lean towards remanufacturing activities under given manufacturing and consumption fees scenarios. The sensitivity analysis reveals that the total surplus and channel profit increases as subsidies increase in all closed-loop supply chain models.

Keywords: Closed-loop supply chain, Remanufacturing, Government subsidies, Fees, Mathematical modelling.

1. Introduction

Environmental issue in terms of CO_2 emission is becoming a major concern for today's Closed-Loop Supply Chain (CLSC) network. Manufacturers and distributors across the North America are regulated by their government to take back the '*end-of-use'* products for the remanufacturing and safe disposal (Mitra, 2016). The recent developments in remanufacturing/recycling in the form of green technology have captured the interest of public and private sectors (Swami and Saha, 2013;. Cohen et al., 2015). Remanufacturing has enormous potential in improving the sustainability in CLSC (Chen and Chang 2012). Several large enterprises such as IBM, Hewlett-Packard, and Xerox have adopted remanufacturing processes within their operations (Dev et al., 2016; Sharma et al., 2016). The manufacturer can either collect used products directly from the customer or through the third party for supporting the reverse logistics (Shi et al., 2011a). The government incentives and taxes are expected to drive the growth of remanufacturing. However, the type of fees and incentives significantly vary from region to region. For example, New York remanufacturers receive the tax credit that is proportionate with the durability of the capital investment (New York State Department of Taxation and Finance, 1991). While in California, customers pay an advance recovery fees for numerous electronics products (Electronics Waste Recycling definition California Act, 2003) and collectors are reimbursed for the cost of remanufacturing and recycling (Council of State

Government, 2009). Similar several examples can be found in the academic literature discussing the implications of the government regulations (Lozano et al., 2016).

It is important for the manufacturer to adjust product returns and sales strategy in response to switching to the remanufacturing programme (Wu, 2012). However, the extent literature highlighted various barriers that restrict the remanufacturing activities such as limited remanufacturing technology, lower environmental preferences and less willingness of customers to pay for the remanufactured products (Guide and Van Wassenhove, 2009; Souza, 2013; Wang and Chen, 2013). Due to these reasons, most of the manufacturers in the developing countries have not participated in the remanufacturing activities actively (Wang et al., 2014). However, the governments in the developing countries are fully conscious of the power of incentives to motivate the manufacturer for remanufacturing activities. For instance, the state council of China supports the development of remanufacturing and recycling activities by providing different kinds of incentives to the manufacturers (Ma et al., 2013; Wang et al., 2014). Such government led initiatives provide the incentives to the manufacturer in the form of tax reduction, relaxation in land allotment policy, one-time subsidy, etc. (Mitra and Webster, 2008; De-Giovanni et al., 2016).

Previous academic literature considers the remanufacturing incentive for manufacturer and collector with green taxation fee under the deterministic environment (Sheu and Chen, 2012). The governments provide subsidies to the manufacturer or collector for collecting and recycling the used-products and simultaneously receives manufacturing fee and consumption fee from the manufacturer and customer respectively. The challenge for the government is to decide whether to provide a subsidy to the manufacturer, collector or end-customer to maximize the total surplus and supply chain profit. The subsidy (or incentive) design literature in the CLSC has ignored remanufacturing approach (Atasu and Subramanian, 2012 ; Cohen et al., 2015) and there exists an evident research gap. Thus, this research considers (re)manufacturing fees and incentives for the manufacturer, collector and customer under different scenarios of the government policies. The objective of this paper is to study the impact of governmental interventions via different subsidies and fees on the total channel profit of the CLSC network.

Consider a CLSC network where manufacturer cooperates with collector to collect the used products from the market. The manufacturer decides the production quantity, transfer price and selling price of the remanufactured and new products. The collector decides the acquisition cost of the used products. The government provides subsidies as well as taxes the manufacturer and customer through manufacturing fee and consumption fee respectively. Under given cicumstances, the research investigates how government's subsidy influences different stakeholders within the CLSC network. The study seeks to address following research questions:

(1) How does the government subsidy influence total channel profit in the CLSC?
(2) Which stakeholder (manufacturer, collector or customer) in the CLSC should be provided with the government subsidy to maximize the total surplus?
(3) What is the resulting effect of government fees and incentives on the end customer?

In practise, policy makers often ignore the governmental subsidies to the manufacturer and collector and considers average values while designing subsidies associated with end-customer. The paper attempts to address some of these aspects by understanding the influence of government financial interventions (taxes and subsidies) on CLSC stakeholders. In order to answer the above research questions, governmental incentives with one-time subsidy have been incorporated in the remanufacturing system. Further, the impact of government subsidy on total channel profit has been investigated under different scenarios. A mathematical model has been developed and analysed considering government interventions to the new and remanufactured products.

The paper is organized as follows. A brief review of the literature is provided in section 2. Section 3 discusses the key notations and assumptions of the modelling framework. Developed mathematical models are discussed in section 4, followed by the assessment of total surplus in section 5. A numerical example to validate the developed model is discussed in section 6. Section 7 discusses sensitivity analysis and managerial insights. Conclusion, limitations and future scope of the study are discussed in section 8.

2. Literature review

The past decades have witnessed enormous increase in the research on remanufacturing and CLSC. The research related to the collection and selling of the remanufactured products is evident through the academic literature (e.g. Atasu et al., 2013; Savaskan et al., 2004; Shi et al., 2011b, De Giovanni and Ramani 2017). However, remanufacturing within CLSC is a relatively new field of research and there exits numerous challenges (Atalay and Atasu, 2008; Guide and Van Wassenhove, 2009). Mitra and Webster (2008) presented a game theoretic framework to gain insights into the decision making of CLSC members and their economic consequence. Within the game theoretic framework for collection and remanufacturing, Savaskan et al. (2004) examined various collection strategies considering different channel structure under '*Stackelberg game'*.

Selected research has emphasized on categorization of the return products, methods of collection and acquisition price management of the used products. It has been widely recognized in the literature (and in practice) that the manufacturer can collect used product from the market. This research has been extended by Atasu et al. (2013) by considering a cost component that captures economies and dis-economies of scale in the collection volume. Shi et al. (2011a) developed a mathematical model to maximize the overall expected profit by simultaneously considering different (selling and acquisition) prices and production quantities for the two channel system under demand uncertain condition. However, the impact of differentiated selling price of manufactured and remanufactured products and collection quantity on the channel profit under different (re)manufacturing systems is unexplored in the literature. Mitra (2016) developed a mathematical model considering a monopolist firm selling new and remanufactured products to both, quality conscious primary customers and price sensitive secondary customers with one-way substitution. In one way substitution, primary customers may give up new products for remanufactured products while secondary customers are unable to buy the new products (Mitra 2016). We extend this research by attempting to study a monopolist firm selling both new and remanufactured products to the incentive driven and fee sensitive customer. The paper explores how the optimal collection rate, selling price and channel profit gets affected, while explicitly considering price and tax sensitive demand in the CLSC network. Sarmah and Jena (2016) studied remanufacturing systems by considering government subsidies provided to the collector. This work has been extended by considering subsidies provided to the customer and manufacturer. Additionally, the effect of government subsidy and tax considering producer and customer surplus is challenged in this paper.

3. **Model notations** and **assumptions**

An analytical model as shown in Figure 1 is formulated for the (re)manufacturing system, where a manufacturer collects old/used products from the market through the collector. New and remanufactured products are produced by the manufacturer and sold to the market with varying product price directly to the customer. Manufacturer and customer pay the government tax for manufacturing and consumption respectively. It is important for the government to know the effect of subsidy in terms of incentives on the remanufacturing activities.

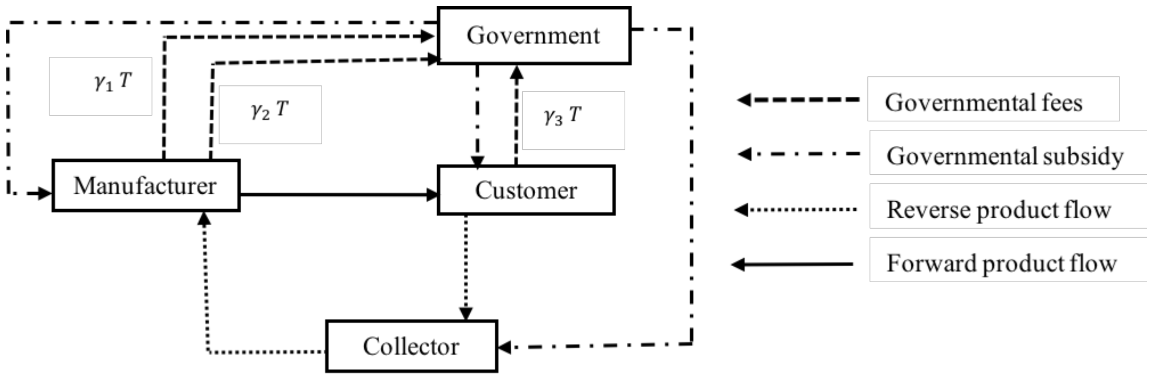

Fig. 1. Conceptual model of remanufacturing system

Table 1: Notation and associated description

Symbol	Description
D_i	Demand of product in the market, where $i \in \{n, r\}$
c	Unit manufacturing cost of the new product
c_r	Unit remanufacturing cost of the used/old product
p_n	Unit selling price of a manufactured product for the manufacturer
p_r	Unit selling price of a remanufactured product for the manufacturer
τ	Return rate of the used product for the manufacturer; $0 \leq \tau \leq 1$
b	Unit transfer price of the used product from the manufacturer
f	Incentive paid to the customer for return of the used product
I	Production collection effort
γ_i	Proportion of tax given by the chain member, subscript i takes the value of 1 and 2, denoting the manufacturer for new and remanufactured product, and 3 for customer respectively
X	Government incentive per unit of the product.
$\tau = \sqrt{\frac{I}{C_L}}$	Return rate
C_L	Scaling parameter
$\delta = c - c_r$	Saving cost
$\prod_K$	Profit function of the channel member. Subscript K takes the values of M and C, denoting the manufacturer and collector
$\prod_{TC}^{N}$	Profit of the total system, where N= subsidies to customer (Model D), subsidies to collector (Model C), subsidies to manufacturer (Model M) and subsidies to collector and manufacturer (Model MC)

Table 1 shows the notations used for the development of mathematical models. In order to develop the CLSC models, it is assumed that the supply chain network planner is centrally coordinating the forward and reverse flow of the products to maximize the total surplus. The demand function is sensitive to price and consumption tax during mathematical modelling. The subscript *n* and *r* indicates the new and remanufactured product respectively.

Assumption 1: *The manufacturing cost of a new product is comparatively higher than a remanufactured product, i.e.,* $c_r < c$ *and* c_r *is the same for all the remanufactured products.*

The remanufacturing cost for reusability is expected to be less than the direct manufacturing cost for a product.

Assumption 2: τ *is the return rate of used product from the customers.* τ *is the fraction of current generation product that would be returned, i.e.,* $0 \leq \tau \leq 1$.

τ is a function of the collection effort denoted by I (Savaskan et al., 2004) and denotes the reverse supply chain performance. The collection effort is usually modelled as a function of the investment for the used product. More the effort put by the manufacturer, more is the investment needed to collect the used product from the market.

Assumption 3: *Fixed payment f is paid by the collector to the customer who returns the used product. Fixed transfer price b is paid by the manufacturer to the collector for collecting the used product and* $b > f$.

The relation between *b* and *f* is given by *f* = *b-e,* where *e* represents the per unit profit margin of the collector. Here, *f* and *b* are not greater than δ due to costly recovery. The model assumes that the government provides incentive of *αX* for unit collected or remanufactured or purchased product ($/unit). Here, $\alpha \epsilon [0,1]$, and represents the fraction of X that goes to the collector or customer at different stages of the CLSC.

Assumption 4: *The demand function of the substitutable product produced by the manufacturer is continuous, deterministic and price (and tax) sensitive and assumed to be in the following form:* $D_n = (\alpha_n - \beta(p_n + \gamma_3 T))$. *The demand function of the remanufactured products is in the following form:* $D_r = (\alpha_r - \beta(p_r + \gamma_3 T))$.

Where α_n and α_r describes the market base parameters for the new and remanufactured product respectively. When both prices are at zero, β is a positive parameter. Here the assumption is that the government receives a total fee of *T* dollar per unit consumed and manufactured product (Council of State Governments 2009); *i.e.* the government receives $\gamma_3 T$ from the customer for purchasing the products and $\gamma_2 T$ and $\gamma_1 T$ from the manufacturer for manufactured and remanufactured products respectively. Similar form of assumptions have been widely used in the CLSC (Heydari et al., 2017; Ma et al., 2013). Linear fees have also been widely accepted in the academic literature for maximizing profit (e.g. Barker 1992; Fershtman and Judd 1987). However, the chain members take their decisions sequentially in the *Stackelberg game*. It is assumed that the price of the remanufactured product and market size are different to the manufactured product. Due to the customer's different quality perception of the remanufactured and manufactured products, the market demand between these two products are expected to be different (Ovchinnikov 2011; Subramanian and Subramanyam 2012).

Assumption 5: *The selling price of the remanufactured product is lower than the new manufactured products.*

Customer perception regarding quality of the remanufactured product is comparatively lower than that of the manufactured product (Wang et al., 2014). Hence they are less likely to pay equal amount to the remanufactured product compared to the new product.

4. Model

The problem is modelled in a two–stage *Stackelberg game*, where the manufacturer is a leader and the collector is a follower in a CLSC network. In practice, the first mover-manufacturer has sufficient bargaining power to act as a *Stackelberg leader*. The manufacturer considers the best response function of the collector in his decision making. The collector making decision after noticing the manufacturer's decision is termed as the follower. The collector takes the responsibility on the behalf of manufacturer to collect the used products from the market at a recovery rate which is determined exogenously. The manufacturer selects the transfer price of the used products using the response function of the collector. In the first period, manufacturer collects the used products from the market through the collector and in the second period the manufacturer sells newly manufactured and remanufactured products to the customers. A single period monopolist model with a unique manufacturer and collector with information sharing across the CLSC network is considered in the paper. This modelling assumption is a reasonable approximation for the electronics products such as video display device. The competition for selling the new and remanufactured products is called as 'outward' or 'forward' price competition. The collector collects used products from the market at a certain fixed price f and receives unit fixed transfer price b from the manufacturer. Later, manufacturer sells their new and remanufactured products to the customer with a selling price p_n and p_r respectively. The manufacturer should certify that the remanufactured products performs well and can substitute the new product at a lower price. The remanufactured products are sold through the retailer or directly to the end customer. The government receives a total fee of T dollar per unit purchased and manufactured from the customer and manufacturer respectively. The government also provides incentive αX dollar per unit collected or remanufactured or purchased ($/unit) by the collector, manufacturer and customer respectively under different stages of the CLSC network. Here it is assumed that the government offers incentives to the customer in terms of replacement subsidy. For an instant, the Chinese government announced that the customers will receive a replacement-subsidy worth 10% of new electronic products such as television, refrigerator, washing machines and computers (Ma et al., 2013). By incorporating above assumptions and parameters for different variables, the paper discusses four government strategies in the CLSC network namely: (i) subsidy to the customer, (ii) subsidy to the collector, (iii) subsidy to the manufacturer and (iv) subsidies to the manufacturer and collector.

4.1 Subsidy to the customer (Model D)

In this model, the collector collects used products from the market and sells them to respective manufacturer and tries to maximize their profit through the collection effort. The manufacturer attempts to maximize their profit by calculating the corresponding selling price of manufactured and remanufactured products based on the the reaction function of the collector. The government receives the consumption tax from the customer and (re)manufacturing fee from the manufacturer and provides the replacement subsidy to the customer for purchasing the remanufactured products. The model incorporates the subsidy part to the remanufactured demand function, as a result the demand of the remanufactured product will increase with the increase in subsidies. New market demand of the remanufactured product is $D_r' = (\alpha_r - \beta(p_r + \gamma_3 T) + \alpha X)$. As a result, the manufacturer will take interest in collecting and remanufacturing the products to maximize the overall profit.

The model solves the two-stage sequential game by using backward induction moving from the second stage of collector's decisions to manufacturer's decision problem in the first stage. The collector's profit function is given by:

$$\underset{\tau}{Max}\Pi_C = (\alpha_n - \beta(p_n + \gamma_3 T))\tau(b - f) - c_L\tau^2 \quad (1)$$

Because $\frac{\partial^2 \Pi_C}{\partial \tau^2} = -2c_L < 0$, because $c_L > 0$. Then (1) shows the concave nature and is maximized when first-order conditions are met. From the first order conditions, the collector sets the collection fraction as:

$$\tau = \frac{(b-f)(\alpha_n - \beta p_n - T\beta\gamma_3)}{2c_L} \quad (2)$$

On the other hand the profit of the manufacturer can be formulated as

$$\underset{p_r\, p_n}{Max}\Pi_M = (p_n - c - \gamma_1 T)D_n + D_r'(p_r - c + \delta\tau - \gamma_2 T) - (\alpha_n - \beta(p_n + \gamma_3 T))\tau b \quad (3)$$

Because $\frac{\partial^2 \Pi_M}{\partial p_n^2} = -2\beta - \frac{b(b-f)\beta^2}{c_L}$, $\frac{\partial^2 \Pi_M}{\partial p_r^2} = -2\beta$ and $\frac{\partial^2 \Pi_M}{\partial p_n \partial p_r} = \frac{\partial^2 \Pi_M}{\partial p_r \partial p_n} = \frac{(b-f)\beta^2\delta}{2c_L}$, the profit function is a negative definite Hessian based on the assumption that $\beta > 0$ *and* $b > f$.

Equation (3) is maximized when first-order conditions are satisfied. From the first order conditions, manufacturer sets the selling price as:

$$p_n = \frac{-(b-f)\beta(X\alpha\delta-\beta\delta p_r-2b\alpha_n+\delta\alpha_r+2bT\beta\gamma_3-T\beta\delta\gamma_3)+2c_L(\alpha_n+\beta(c+T\gamma_1-T\gamma_3))}{2\beta(b(b-f)\beta+2c_L)} \quad (4)$$

$$p_r = \frac{2c_L(X\alpha+c\beta+\alpha_r+T\beta\gamma_2-T\beta\gamma_3)+(b-f)\beta\delta(\beta p_n-\alpha_n+T\beta\gamma_3)}{4\beta c_L} \quad (5)$$

$$b = \frac{-X\alpha\delta+f\beta p_n+\beta\delta p_r-f\alpha_n-\delta\alpha_r+fT\beta\gamma_3+T\beta\delta\gamma_3}{2(\beta p_n-\alpha_n+T\beta\gamma_3)} \quad (6)$$

Solving equation (4) and (5) simultaneously, the optimal solution (p_n^* , p_r^*) can be derived.

Total profit of the CLSCs can be obtained as:

$$\prod_{TC}^{D}{}^{*} = \prod_M{}^{*} + \prod_C{}^{*}$$

4.2 Subsidy to the collector (Model C)

In this model, the collector collects the used products from the market and sells it to the respective manufacturer and tries to maximize their profit through the collection effort. In this case the government receives the consumption tax from the customer and remanufacturing fee from the manufacturer. The government also provides the subsidy to the collector for collecting the used products from the market. As a result collector affords the collection risk without putting much pressure on the manufacturer to buy it.

The collector's profit function is given by:

$$\underset{\tau}{Max}\,\Pi_C = \big(\alpha_n - \beta(p_n + \gamma_3 T)\big)\tau(b - f + \alpha X) - c_L\tau^2 \quad (7)$$

From the second-order conditions, we get $\frac{\partial^2 \Pi_C}{\partial \tau^2} = -2c_L < 0$ Π_C is concave in τ, whenever $c_L > 0$. Using the first-order conditions to derive the best response to the return rates gives:

$$\tau = \frac{(b-f+X\alpha)(\alpha_n-\beta p_n-T\beta\gamma_3)}{2c_L} \quad (8)$$

Whereas the profit of the manufacturer can formulated as

$$\underset{p_r\,p_n}{Max}\,\Pi_M = (p_n - c - \gamma_1 T - \tau b)D_n + D_r(p_r - c + \delta\tau - \gamma_2 T) \quad (9)$$

Because $\frac{\partial^2 \Pi_M}{\partial p_n^2} = -2\beta - \frac{b(b-f+X\alpha)\beta^2}{c_L}$, $\frac{\partial^2 \Pi_M}{\partial p_r^2} = -2\beta$ and $\frac{\partial^2 \Pi_M}{\partial p_n \partial p_r} = \frac{\partial^2 \Pi_M}{\partial p_r \partial p_n} = \frac{(b-f+X\alpha)\beta^2\delta}{2c_L}$, the profit function is a negative definite Hessian from the assumption that $\beta > 0, \delta > 0, and\ b > f$.

$$p_n = \frac{-(b-f+X\alpha)\beta(-\beta\delta p_r-2b\alpha_n+\delta\alpha_r+2bT\beta\gamma_3-T\beta\delta\gamma_3)+2c_L(\alpha_n+\beta(c+T\gamma_1-T\gamma_3))}{2\beta(b(b-f+X\alpha)\beta+2c_L)} \quad (10)$$

$$p_r = \frac{(b-f+X\alpha)\beta\delta(\beta p_n-\alpha_n+T\beta\gamma_3)+2c_L(\alpha_r+\beta(c+T\gamma_2-T\gamma_3))}{4\beta c_L} \quad (11)$$

$$b = \frac{(f-X\alpha)\beta p_n+\beta\delta p_r-f\alpha_n+X\alpha\alpha_n-\delta\alpha_r+fT\beta\gamma_3-TX\alpha\beta\gamma_3+T\beta\delta\gamma_3}{2(\beta p_n-\alpha_n+T\beta\gamma_3)} \quad (12)$$

Solving (10) and (11) simultaneously, the optimal solution (p_n^*, p_r^*) can be derived.

Total profit of the CLSCs can be obtained as:

$$\prod_{TC}^{C\ *} = \prod_M{}^* + \prod_C{}^*$$

4.3 Subsidy to the manufacturer (Model M)

In this case, the government receives the consumption tax from the customer and (re)manufactured fee from the manufacturer. The government also provides the subsidy (in terms of incentives) to the manufacturer for remanufacturing the products after collecting used products from the market. As a result, the manufacturer takes an interest in recycling and remanufacturing within a CLSC network to achieve government's green goals.

The collector's profit function is given by:

$$\underset{\tau}{Max}\,\Pi_C = (\alpha_n - \beta(p_n + \gamma_3 T))\tau(b - f) - c_L\tau^2 \quad (13)$$

From the second-order conditions, we get $\frac{\partial^2 \Pi_C}{\partial \tau^2} = -2c_L < 0$ Π_C is concave in τ, whenever $c_L > 0$. Using the first-order conditions to derive the best response to the return rates gives:

$$\tau = \frac{(b-f)(\alpha_n - \beta p_n - T\beta\gamma_3)}{2c_L} \quad (14)$$

And the profit of the manufacturer can be written as follows:

$$\underset{p_r\,p_n}{Max}\,\Pi_M = (p_n - c - \gamma_1 T - \tau b)\,D_n + D_r(p_r - c + \delta\tau - \gamma_2 T + X\alpha) \quad (15)$$

Because $\frac{\partial^2 \Pi_M}{\partial p_n^2} - 2\beta - \frac{b(b-f)\beta^2}{c_L}, \frac{\partial^2 \Pi_M}{\partial p_r^2} = -2\beta$ and $\frac{\partial^2 \Pi_M}{\partial p_n \partial p_r} = \frac{\partial^2 \Pi_M}{\partial p_r \partial p_n} = \frac{(b-f)\beta^2\delta}{2c_L}$, the profit function is a negative definite Hessian based on the assumption that $\beta > 0, \delta > 0, and\ b > f$. While making this decision, manufacturer considers the best response function of the collector. Substituting equation (14) in to (15), we can derive the optimal value of the (p_n, p_n) using the first-order conditions to derive the best response to the selling price:

$$p_n = \frac{-(b-f)\beta(-\beta\delta p_r - 2b\alpha_n + \delta\alpha_r + 2bT\beta\gamma_3 - T\beta\delta\gamma_3) + 2c_L(\alpha_n + \beta(c + T\gamma_1 - T\gamma_3))}{2\beta(b(b-f)\beta + 2c_L)} \quad (16)$$

$$p_r = \frac{(b-f)\beta\delta(\beta p_n - \alpha_n + T\beta\gamma_3) + 2c_L(\alpha_r + \beta(c - X\alpha + T\gamma_2 - T\gamma_3))}{4\beta c_L} \quad (17)$$

$$b = \frac{f\beta p_n + \beta\delta p_r - f\alpha_n - \delta\alpha_r + fT\beta\gamma_3 + T\beta\delta\gamma_3}{2\beta p_n - 2\alpha_n + 2T\beta\gamma_3} \quad (18)$$

Solving equation (16) and (17) simultaneously, the optimal solution (p_n^*, p_r^*) can be derived.

Total profit of the CLSCs can be obtained as:

$$\prod_{TC}^{M\ *} = \prod_M{}^* + \prod_C{}^*$$

4.4 Subsidies to the manufacturer and collector (Model MC)

In this section, we extended the model by simultaneously incorporating remanufacturing subsidy to the manufacturer and collecting incentive to the collector; as well as (re)manufacturing fee for the manufacturer and a consumption fee for the customers. The government provides αX to the manufacturer for remanufacturing the used products, whereas (1-α)X to the collector for the units collected. In other cases, we assumed that the government receives a total fee of T dollars per unit for the (re)manufactured or purchased product.

With the introduction of the incentives for the manufacturer and collector simultaneously, the new profit function for the collector is given by:

$$\underset{\tau}{Max}\,\Pi_C = \left(\alpha_n - \beta(p_n + \gamma_3 T)\right)\tau(b - f + X(1-\alpha)) - c_L\tau^2 \qquad (19)$$

From the second-order conditions, we get $\frac{\partial^2 \Pi_C}{\partial \tau^2} = -2c_L < 0$ Π_C is concave in τ, whenever $c_L > 0$. Using the first-order conditions to derive the best response to the return rates gives:

$$\tau = \frac{(b-f+X-X\alpha)(\alpha_n-\beta p_n-T\beta\gamma_3)}{2c_L} \qquad (20)$$

Whereas the manufacturer's profit maximizing profit can be formulated as:

$$\underset{p_r\,p_n}{Max}\,\Pi_M = (p_n - c - \gamma_1 T - \tau b)D_n + D_r(p_r - c + \delta\tau - \gamma_2 T + X\alpha) \qquad (21)$$

Because $\frac{\partial^2 \Pi_M}{\partial p_n^2} = -2\beta - \frac{b(b-f+X-X\alpha)\beta^2}{c_L}$, $\frac{\partial^2 \Pi_M}{\partial p_r^2} = -2\beta$ and $\frac{\partial^2 \Pi_M}{\partial p_n \partial p_r} = \frac{\partial^2 \Pi_M}{\partial p_r \partial p_n} = \frac{(b-f+X-X\alpha)\beta^2\delta}{2c_L}$, the profit function is a negative definite. Hessian based on the assumption that $\beta > 0$ *and* $b > f$. Equation (3) is maximized when first-order conditions are satisfied. From the first order conditions, the manufacturer sets the selling price as:

$$p_n = \frac{2c_L(\alpha_n+\beta(c+T\gamma_1-T\gamma_3))-(b-f+X-X\alpha)\beta(-\beta\delta p_r-2b\alpha_n+\delta\alpha_r+2bT\beta\gamma_3-T\beta\delta\gamma_3)}{2\beta(b(b-f+X-X\alpha)\beta+2c_L)} \qquad (22)$$

$$p_r = \frac{-(-c\beta+X\alpha\beta-\alpha_r-T\beta\gamma_2+T\beta\gamma_3)+\frac{(b-f+X-X\alpha)\beta\delta(\beta p_n-\alpha_n+T\beta\gamma_3)}{2c_L}}{2\beta} \qquad (23)$$

$$b = \frac{(f+X(-1+\alpha))\beta p_n+\beta\delta p_r-f\alpha_n+X\alpha_n-X\alpha\alpha_n-\delta\alpha_r+fT\beta\gamma_3-TX\beta\gamma_3+TX\alpha\beta\gamma_3+T\beta\delta\gamma_3}{2(\beta p_n-\alpha_n+T\beta\gamma_3)} \qquad (24)$$

Total profit of the CLSCs can be obtained as:

$$\Pi_{TC}^{MC^*} = \Pi_M{}^* + \Pi_C{}^*$$

Proposition 1*: When α>0.5, the fraction of the collection (τ) of the used products in the collector subsidies case is higher compared to the other three cases considering the same marginal profit for the collector in all cases. Whereas, the fraction of the collection (τ) of the* *used products is more in the manufacturer and collector subsidies compared to other three cases when α<0.5.*

Proof: From the analysis, we found that from equation (2) and (12);

$$\tau^D = \tau^M = \frac{(b-f)(\alpha_n-\beta p_n-T\beta\gamma_3)}{2c_L}$$

And from equation (7) and (17)

$\tau^C = \frac{(b-f+X\alpha)(\alpha_n-\beta p_n-T\beta\gamma_3)}{2c_L}$ and $\tau^{MC} = \frac{(b-f+X-X\alpha)(\alpha_n-\beta p_n-T\beta\gamma_3)}{2c_L}$ respectively

When 1> α >1/2

$(b-f+X\alpha) > (b-f+X-X\alpha)$ as X > 0

For that $\tau^C > \tau^{MC} > \tau^D = \tau^M$

But when ½ > α >0

$(b-f+X\alpha) < (b-f+X-X\alpha)$, For that $\tau^D = \tau^M < \tau^C < \tau^{MC}$

Proposition 2*: In the manufacturer subsidies, the manufacturer is a Stackelberg leader, he will decide the collection of used product from the market because of the government subsidies. For the manufacturer transfer price increases as the collection of the used product increases.*

Proof: From the equation (12), the fraction of the used items collected from the market is as follows:

$\tau^M = \frac{\lambda(D_n)}{2c_L}$ Where $b = \lambda + f$

$\frac{2c_L}{D_n} = \frac{\lambda}{\tau^D}$ >1 as $c_L > D_n$

If the manufacturer wants to collets the 50% of the new products sold in the previous period then the manufacturer has to decide the transfer price as follows:

If $\tau^M = \frac{1}{2}$ then $b = \frac{c_L}{D_n} + f$

If the manufacturer wants to collect more than the 50% of the new product;

$1 \geq \tau^M > \frac{1}{2}$ then $f + \frac{c_L}{D_n} < b \leq \frac{2c_L}{D_n} + f$.

If the manufacturer wants to collects the used products 50% lower than the new product sold in the previous period, then the manufacturer has to decide the transfer price as follows:

When $0 \leq \tau^D < \frac{1}{2}$, then $f \leq b < f + \frac{c_L}{D_n}$

Proposition 3*: The selling price of the remanufactured product is higher in the customer subsidy compared to other three cases.*

Proof: ${p_r}^D - {p_r}^C = \frac{X\alpha(2c_L+\beta\delta D_n)}{4\beta c_L} > 0$

$${p_r}^D - {p_r}^M = \frac{X\alpha(1+\beta)}{2\beta} > 0$$

$${p_r}^D - {p_r}^{MC} = \frac{2X\alpha(1+\beta)c_L-(2b-2f+X-X\alpha)\beta\delta(\beta p_n-\alpha_n+T\beta\gamma_3)}{4\beta c_L} > 0$$

As $2X\alpha(1+\beta)c_L > (2b-2f+X-X\alpha)\beta\delta(\beta p_n-\alpha_n+T\beta\gamma_3)$.

X >0, α >0, β > 0, T >0, and $c_L > 0$.

It is observed that when government provides subsidy to the customer, the customer is ready to take the remanufactured product with higher price compared to other three subsidy cases.

Proposition 4*: Under the government revenue neutrality in the manufacturer and collector subsidies case, the relation between total fees and incentives is as follows:*

$T = X((1-\alpha)\tau+\alpha)$ *When* $D_n = D_r$

Proof: In the context of the model, the revenue neutrality is given by

$$\left(\alpha_n-\beta(p_n+\gamma_3 T)\right)\gamma_3 T + \left(\alpha_n-\beta(p_n+\gamma_3 T)\right)\gamma_1 T + \left(\alpha_r-\beta(p_r+\gamma_3 T)\right)\gamma_2 T = \left(\alpha_r-\beta(p_r+\gamma_3 T)\right)X\tau(1-\alpha) + \left(\alpha_n-\beta(p_n+\gamma_3 T)\right)X\alpha \quad (25)$$

Where the left hand side of equation (25) represents the total amount of the fees and the right hand sides of equation (25) represents the total amount of the incentives. We can simplify the equation (25) to become:

$$T = \frac{X((1-\alpha)\tau+\frac{D_r}{D_n}\alpha}{\gamma_1+\gamma_3+\frac{D_r}{D_n}\gamma_2} \quad (26)$$

When $D_n = D_r$, the new equation is given by:

$T = X((1-\alpha)\tau+\alpha)$, because $\gamma_1+\gamma_2+\gamma_3 = 1$

5. Total Surplus

We study the effect of government subsidy on the manufacturer, collector and customer using customer surplus and producer surplus as a metric. Hence the aggregate level of Total Surplus (TS) under different government subsidies need to be compared. TS surplus is the total benefit to the society from the production and consumption of the products. Customer surplus (CS) is an economic measure of the consumer satisfaction calculated by analysing the difference between what consumer would be willing to pay and the actual market price (Cohen et al., 2015). The paper assumes that the new product demand function in assumption 4 is $Q^{-1}(D_n)$; Where $Q^{-1}(D_n) = p_n(D_n)$ denotes the inverse new product demand curve. Similarly for the remanufactured product demand curve in all the cases except customer subsidies is $Q^{-1}(D_r) = p_r(D_r)$. The demand curve in customer subsidies is $Q^{-1}(D_r') = p_r(D_r')$. This can be computed as the area under demand curve above the market price (See Vives, 2001 for more information):

$CS_n = \int_0^{D_n^*} Q^{-1}(D_n)\,\partial D_n - D_n^* p_n^*$ and $CS_r = \int_0^{D_r^*} Q^{-1}(D_r)\,\partial D_r - D_r^* p_r^*$

The Producer Surplus (PS) is the difference between the revenue producer generates by selling a product and the minimum amount they would accept to produce it. Here PS is defined as the sum of all profits of the collector and manufacturer and thus we have represented PS = $\prod_M{}^{N} + \prod_C{}^{N}$. The incentive and fee, X and T are tested as a passive parameters. In this case, we treat the incentive and fee as an active decision variables for the government to maximize the total surplus. Therefore the government has the goal of TS maximization which is given by:

$$Max_X\, TS = CS_n{}^N + CS_r{}^N + \prod_M{}^N + \prod_C{}^N$$

Where N = D, C, M and MC for the customer, collector, manufacturer and combined manufacturer and collector subsidy respectively. The first order necessary condition that leads to the optimal solution of the X* and T* for all the cases is given as:

For Model D

$$X^* = \frac{(k\beta-\alpha_r)\gamma_1+(-k\beta+\alpha_n)\gamma_2+(\alpha_n-\alpha_r)\gamma_3}{\alpha(\gamma_1+\gamma_3)} \tag{27}$$

$$T^* = \frac{-k\beta+\alpha_n}{2\beta(\gamma_1+\gamma_3)} \tag{28}$$

For Model C:

$$X^* = \frac{2(c\beta-\alpha_r)\gamma_1+(-k\beta+\alpha_n)\gamma_2+(\alpha_n-\alpha_r)\gamma_3}{\alpha\beta(\gamma_1+\gamma_3)} + \frac{(\alpha_n+c\beta)}{10\alpha} \tag{29}$$

$$T^* = \frac{\alpha_n+(-k\beta+\alpha_n)\gamma_2}{2\beta\,(\gamma_1+\gamma_3)} - \frac{(b\gamma_3+\alpha_r+10\gamma_2)17}{2c_L} \tag{30}$$

For Model M

$$X^* = \frac{(k\beta-\alpha_r)\gamma_1+(-k\beta+\alpha_n)\gamma_2+(\alpha_n-\alpha_r)\gamma_3}{\alpha\beta(\gamma_1+\gamma_3)} \tag{31}$$

$$T^* = \frac{-k\beta+\alpha_n}{2\beta(\gamma_1+\gamma_3)} \tag{32}$$

For Model MC

$$X^* = \frac{2(c\beta-\alpha_r)\gamma_1+(-c\beta+\alpha_n)\gamma_2+(\alpha_n-\alpha_r)\gamma_3}{2\alpha\beta(\gamma_1+\gamma_3)} + \frac{(\alpha_n+c\beta)}{5\alpha} \quad (33)$$

$$T^* = \frac{\alpha_n+(-k\beta+\alpha_n)\gamma_2}{2\,(\gamma_1+\gamma_3)} - \frac{(b\gamma_3+\alpha_r+10\gamma_2)}{2c_L} \quad (34)$$

Proposition 5: *The fees in the model D and Model M are same, whereas subsidies in the Model D is β times that of the Model M.*

Proof: From the equation (24 and 28), the tax in both the model is same i.e.

$T^D = T^M = \frac{-k\beta+\alpha_n}{2\beta(\gamma_1+\gamma_3)}$,

Whereas, for subsidies in both the model (equation 23 and 27) is given as follows:

$\frac{X^D}{X^M} = \beta$

$X^D = \beta X^M$

From the proposition 5, it is observed that when the government provided subsidies are higher to the customer compared to the manufacturer; the customer will take more interest in purchasing the remanufactured product and at the same time will return the used products. However, (re)manufacturing fee for the manufacturer and a consumption fee for the customers is same for the Model D and Model M respectively.

6. Numerical example

A numerical study is carried out to illustrate the models and associated results. Here, the hypothetical data used for the numerical example is consistent with extant academic literature (e.g. Heydari et al., 2017; Shi et al., 2011a; Wu 2012). In addition, in order to better visualize the behavior of the proposed model and for its simplicity, a sensitivity analysis on few model parameters is conducted. The following parameter values are considered for illustrating the developed models: $\alpha_n = 40, \beta = 1, c = 10, \alpha_r = 40, \delta = 0.5, c_L = 200, f = 5, \alpha = 0.5$ and $\gamma_1 = \gamma_2 = \gamma_3 = 0.166$. The results presented in Table 2 show that the channel profit is higher in *Model M* compared to other models. This is because of the cost savings made for the remanufactured product from remanufacturing systems and government incentives. In *Model D*, the manufacturer sells the remanufactured products and manufactured products with a higher price compared to other models because of the governmental incentives to the customer.

Table 2: Results of four different remanufacturing models

Model	p_r	p_n	τ	B	X	T	Π_C	Π_M	Π_{TC}	TS
D	25.40	31.81	0.263	08.50	20	45.10	1.68	68.91	69.91	95.61
C	19.57	30.19	0.802	12.50	50	53.57	13.10	6.54	19.64	59.45
M	13.25	29.68	0.697	10.50	20	45.18	9.37	86.60	95.97	128.20
MC	13.61	28.31	0.593	11.23	15.60	62.45	7.14	24.10	31.24	44.32

Incentive and price sensitive customers are inclined towards the remanufacturing products compared to the quality sensitive customers (Guide and Van Wassenhove, 2009). However, total channel profit and collection of the used products in *Model D* is comparatively lower than *Model M.* This is because of the lower total (re)manufacturing costs in *Model M*. In *Model M*, the government provides subsidies to the manufacturer and hence takes the higher interest in the remanufacturing activities. Due to this the manufacturer collects more used products through a collector compared to the *Model D*. In *Model C*, it is observed that the collection of the used products is higher compared to the other models. In *Model C,* the collector receives government subsidies and manufacturer transfer price for the collection of the used products. The collector's profit depends upon the collection of the used products from the market. For increasing the profit, the collector puts more efforts in collecting the used products compared to the other models.

The results in Table 2 also reveal that the governmental fees in both *Model M* and *Model D* is equal; whereas governmental fees are higher in *Model MC* compared to the other models. The government collects more fees from the manufacturer and customers because of high production in *MC model*. This insight corresponds with the earlier findings made by Sheu and Chen (2012), that the governmental fee may not be a financial burden on the manufacturer as evidenced through this study. Total surplus is more in *Model M* compared to all other models. The government aims to maximize the total surplus, as a result, the environmental performance is maximized by minimizing the disposal of the used products. From the above analysis, in case of price-sensitive customer, we can infer that the best option is to maintain *M model* over *D, C and MC models*.

7. Sensitivity analysis

Impact of Tax ($\gamma_1 = \gamma_2 = \gamma_3 = \gamma$)

The impact of manufacturing and purchase tax γ on the total channel profit for the four cases are analyzed in this section. From Figure 2, it is observed that the channel profit decreases as manufacturing and purchase tax increases in all the four models. However, *Model M* produces highest channel profit compared to other three models as the price competition increases. Due to the subsidies, the manufacturer tends to collect more used products and remanufacture them. The overall cost of manufacturing decreases and leads to the profit as a result of this behavior. It is also observed that channel profit in *Model C* is less compared to *Model D* and *Model MC.* Under the government subsidies, the remanufactured product’s price compels the new product’s price to generate additional revenue. On the other hand, the manufacturer generates less revenue from the remanufactured products as tax increases under *Model C;* This is because of the lower demand for the remanufactured and manufactured products. As a result of this the total channel profit decreases in *Model C* compared to the other models. In *model D*, due to governmental subsidies, customers are more interested in returning the used products and purchasing the remanufactured products. However customers are not willing to pay a higher price for the remanufactured products, as the quality of these products is perceived to be lower than the newly manufactured products. As a result, the profit of the total channel is comparatively lower than *Model M*. The total surplus increases as tax increases in all the four models as observed in Figure 3. However, it is highest in *Model M* compared to the other three models due to higher production and consumption of the products. It is deduced that the best option is to maintain *Model M* compared to other models, as the value of γ is sufficiently large.

Impact of governmental Subsidies (α)

The impact of governmental subsidies α on the total profit and TS is studied here in Figure 4 and Figure 5 respectively. It can be inferred that increasing governmental subsidies α is beneficial to the profit of the total channel in all the four models. When government subsidies increases, *model M* makes the higher profit as compared to the other three models. Due to higher subsidies, the manufacturer does not hesitate to opt for the remanufacturing as they clearly see the economic benefit associated with the activity. However in *model D, Model C* and *Model MC*, manufacturer take interest in the remanufacturing on the basis of customer perception of the remanufactured products. For this reason the channel profit and TS are higher in *Model M* compared to other three models. It is also observed that in *Model D and Model M*, demand level and total revenue is higher compared to other two systems with an increase in the governmental subsidies. The total profit and TS increase marginally in *Model M* compared to *Model D and Model MC*. Therefore, the best option is to maintain *Model M* as compared to other *C, D and MC* model.

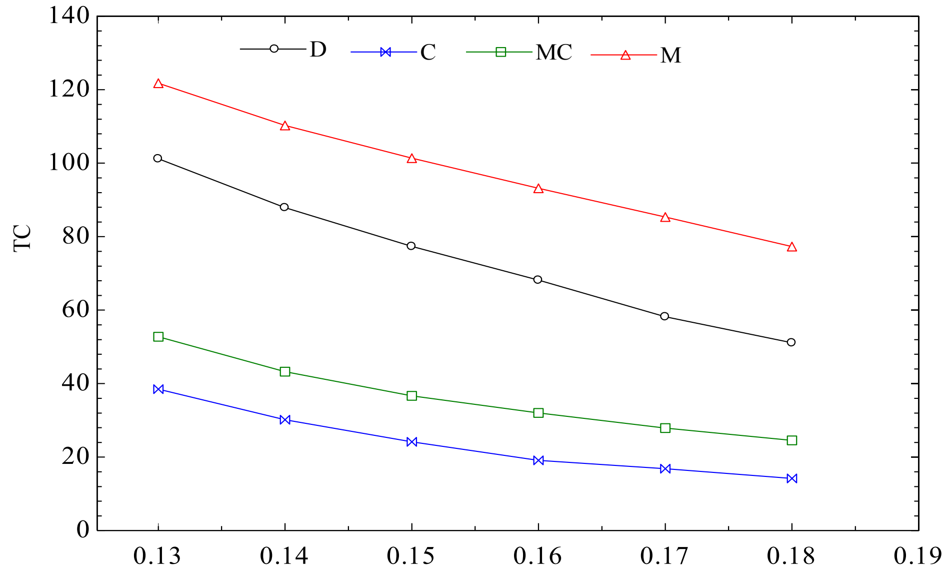

Fig. 2. Channel profit for the four models for different values of γ

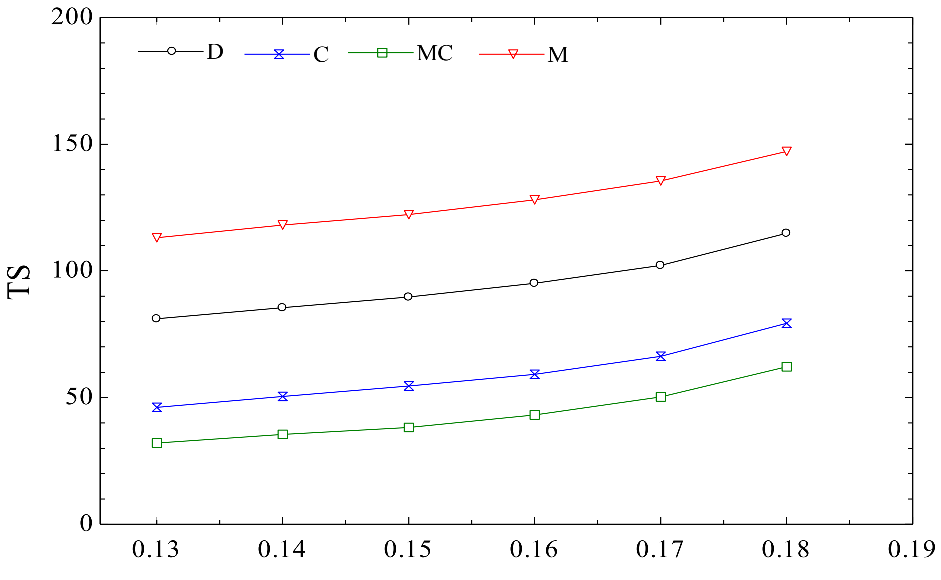

Fig.3. TS for the four models for different values of γ

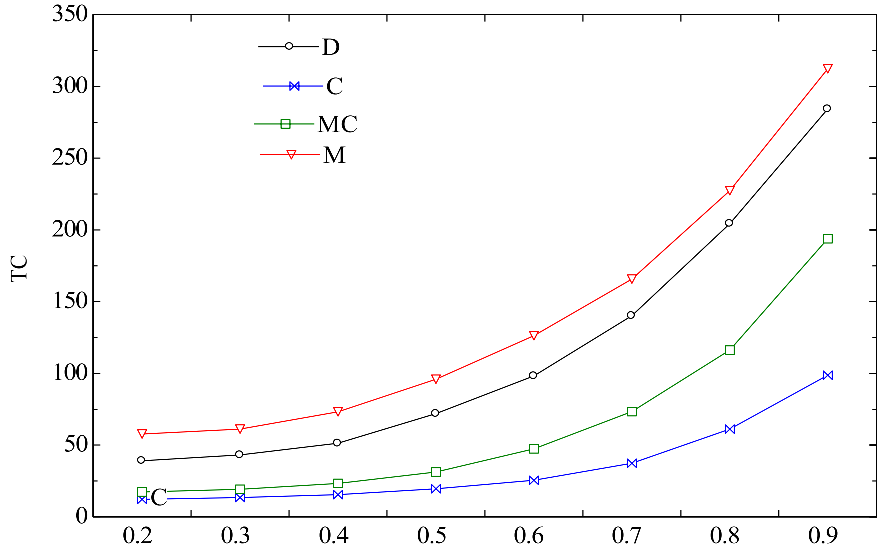

Fig. 4. Channel profit for the four models for different values of α

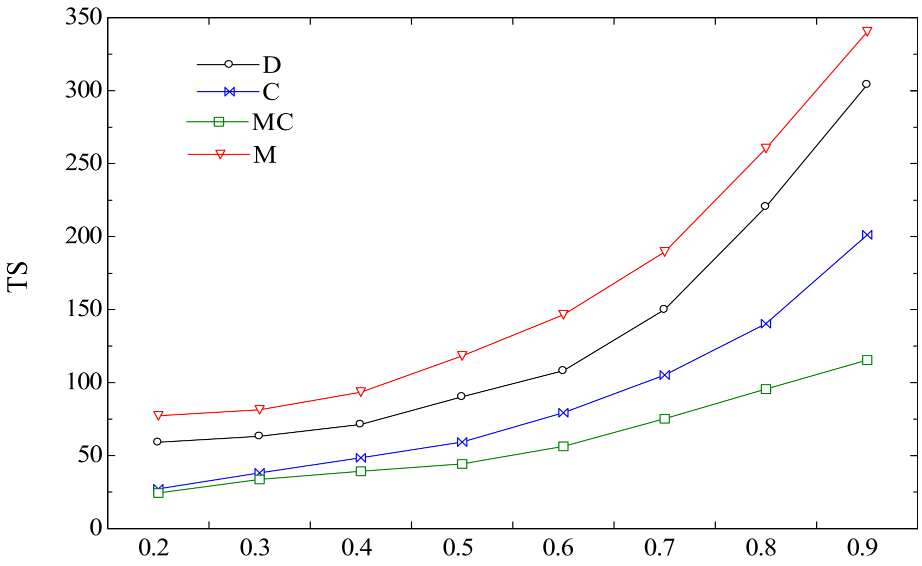

Fig. 5. TS for the four models for different values of α

8. Conclusion

The paper provides insights into the use of taxes and subsidies for maximizing the total supply chain profit of the CLSC network. It is critical to know the impact of government subsidies on the remanufacturing processes (Cohen et al., 2015; Sheu and Chen, 2012). It is evident through the study that the new and remanufactured products under price and fee sensitive demand can provide structural insights into the optimal anticipative CLSC decisions. There is an evident need for developing a cooperative solution by considering incentives strategies in a dynamic CLSC (De Giovanni et al., 2016). By considering different scenarios, the models provide insights for the governmental policy development. The models also reflect on the customer behaviour and channel profit in different CLSC scenarios. They further support in the decision making for the government for maximizing the total surplus of the network. The analysis provides answer to the first research question by understanding the effect of government intervention via different subsidies and fees on the economic efficiency of the CLSC network.

The paper develops four different CLSC models under price and tax sensitive market demand. Based on the comparison and sensitivity analysis, some of the observations are presented. It is observed that *Model M* is the best scheme in terms of channel profit as well a total surplus followed by model *D, MC*, and *C*. However, one of the interesting results between *Model C* and *Model MC* is that *Model MC* provides higher channel profit, while *Model C* provides higher total surplus under government intervention. It is found that the manufacturer concerns regarding the potential negative impact of remanufacturing may go beyond the fear of customer perception regarding remanufactured products. This observation along with the associated findings answers the second research question. It is evident that the government subsidies significantly impact on total surplus and channel profit, if the manufacturer and collector are proactively involved in the reverse logistics process. The market price of the remanufactured product is higher if the subsidy is provided to the customer. The results reveal that the value of total profit increases as the subsidies increases in all four models, validating the economic theories. The presence of government subsidies has a positive impact on the manufacturer towards remanufacturing and equally positive impact on the customer behaviour for buying and returning the new and used products respectively. The research evidently shows the impact of government initiatives on customer's buying behaviour, thereby answering the third research question. In contrast to the past research, the channel structure proposed in this paper is comprehensive as it captures government participation (via subsidies and fees) towards economic and environmental sustainability.

Every study has few limitations. While the models discussed in this paper focuses on linear price and fees sensitive demand. It would be interesting to examine the impact of non-linear demand on the CLSC performance under government interventions. Numerical study has considered hypothetical values for the selected parameters, however in practice they are stochastic in nature. Future research can re-model the problem using uncertainty or fuzzy theory to capture such stochasticity. Further, the research can design two-stage leader-follower models, where a collector is a leader and the manufacturer is the follower. Another challenging avenue for the future research is to observe how stakeholder competition affects the outcome of the government subsidies. The research is expected to benefit CLSC network stakeholders and governments in encouraging remanufacturing activities to achieve channel profit.

References

Atasu, A., Guide, D. and Van Wassenhove, N. (2008). Product Reuse Economics in Closed-Loop Supply Chain Research. *Production and Operations Management*, *17*(5), 483–496.

Atasu, A. and Subramanian, R. (2012). Extended producer responsibility for e-waste: Individual or collective producer responsibility? *Production and Operations Management*, *21*(6), 1042–1059.

Atasu, A., Toktay, B. and Van Wassenhove, L. (2013). How collection cost structure drives a manufacturer's reverse channel choice. *Production and Operations Management*, *22*, 1089–1102.

Baker, P. (1992). Incentive Contracts and Performance Measurement. *The Journal of Political Economy,* 100(3), 598-614

Carraro, C. and Topa, G. (1995). Taxation and environmental innovation. Control and Game-Theoretic Models of the Environment. *Annals of the International Society of Dynamic Games*, 109-139.

Chen, J. M. and Chang, C. I. (2012). The economics of a closed-loop supply chain with remanufacturing. *Journal of the Operational Research Society*, *63*(10), 1323-1335.

Council of State Government, Electronic Waste Recycling Act California, 2009.

Cohen, M., Lobel, R. and Perakis, G. (2015). The Impact of Demand Uncertainty on Consumer Subsidies for Green Technology Adoption. *Management Science*, 62(5), 1235-1258.

De Giovanni, P., Reddy, P. V. and Zaccour, G. (2016). Incentive strategies for an optimal recovery program in a closed-loop supply chain. *European Journal of Operational Research*, 249(2), 605-617.

De Giovanni, P. and Ramani, V. (2017). Product cannibalization and the effect of a service strategy. *Journal of the Operational Research Society*, 1-17.

Dev, N. K., Shankar, R. and Choudhary, A. (2017). Strategic design for inventory and production planning in closed-loop hybrid systems. *International Journal of Production Economics* 183, 345-353.

Electronic Waste Recycling Act of 2003, CAL. PUB. RES. CODE § 42461(d) (West 2004).

Fershtman, C. and Judd. K. L. (1987). Equilibrium Incentives in Oligopoly. *The American Economic Review,* 77(5), 927-940

Galiana, D. Motto, A and F. B. (2003). Reconciling Social Welfare, Agent Profits, and Consumer Payments in Electricity Pools. *IEEE Transactions On Power Systems*, *18*, 452–459.

Government Relations: The Remanufacturing Institute. http://www.reman.org/GovRelations_main.htm (accessed on 08.08.17)

Guide, V. D. R. and Van Wassenhove, L. N. (2009). OR FORUM--The Evolution of Closed-Loop Supply Chain Research. *Operations Research*, *57*(1), 10–18.

Heydari, J., Govindan, K. and Jafari, A. (2017). Reverse and closed loop supply chain coordination by considering government role. *Transportation Research Part D: Transport* *and Environment*, *52*, 379-398.

Jena, S K and Sarmah S.P.(2014). Price comptition and co-operation in a duopoly closed-loop supply chain. *International Journal of Production Economics* 146, 346–60.

Jena, S K. and Sarmah. S. P.(2015). Measurement of consumers' return intention index towards returning the used products. *Journal of Cleaner Production*. 180(1), 818 – 829.

Lozano, J. M., Albareda, L., Ysa, T., Roscher, H. and Marcuccio, M. (2016). Governments and corporate social responsibility: Public policies beyond regulation and voluntary compliance. *Springer*.

Ma, W. M., Zhao, Z., and Ke, H. (2013). Dual-channel closed-loop supply chain with government consumption-subsidy. *European Journal of Operational Research*, 226(2), 221–227.

Mitra, S. (2016). Optimal pricing and core acquisition strategy for a hybrid manufacturing/remanufacturing system. *International Journal of Production Research*. 54(5), 1285-1302.

Mitra, S. and Webster, S. (2008). Competition in remanufacturing and the effects of government subsidies. *International Journal of Production Economics*, 111(2), 287–298.

New York State Department of Taxation and Finance (1991), Taxpayer Services Division. (n.d.). *Technical Services Bureau. New York State*.

Ovichinnikon, A.(2011). Revenue and Cost Management for Remanufactured Products. *Production and Operations Management*, 20(6), 824–840.

Sarmah, S. and Jena, S. (2016). Modeling of remanufacturing system considering government incentive, 27^{th} *Production and Operations Management conference*, Orlando, FL, USA, 2016

Savaskan, R. C., Bhattacharya, S. and Van Wassenhove, L. N. (2004). Closed-Loop Supply Chain Models with Product Remanufacturing. *Management Science*, 50(2), 239–252.

Savaskan, R. C. and Van Wassenhove, L. N. (2006). Reverse Channel Design: The Case of Competing Retailers. *Management Science*, *52*(1), 1–14.

Sharma, V., Garg, S. K. and Sharma, P. B. (2016). Identification of major drivers and roadblocks for remanufacturing in India. *Journal of Cleaner Production*, 112, 1882-1892.

Sheu, J. B. (2011). Bargaining framework for competitive green supply chains under governmental financial intervention. *Transportation Research Part E: Logistics and Transportation Review*, *47*(5), 573–592.

Sheu, J. B. and Chen, Y. J. (2012). Impact of government financial intervention on competition among green supply chains. *International Journal of Production Economics*, *138*(1), 201–213.

Shi, J., Zhang, G. and Sha, J. (2011a). Optimal production and pricing policy for a closed loop system. *Resources, Conservation and Recycling*, *55*(6), 639–647.

Shi, J., Zhang, G. and Sha, J. (2011b). Optimal production planning for a multi-product closed loop system with uncertain demand and return. *Computers and Operations Research*, *38*(3), 641–650.

Subramanian,R. and Subramanyam,R.(2012). Key factors in the market for the remanufactured products. *Manufacturing & Service Operations Management,*14(2), 315-326.

Souza, G. (2013). Closed-Loop Supply Chains: A Critical Review, and Future Research*. *Decision Sciences*, *44*(1), 7–38.

Swami, S. and Shah, J. (2013). Channel coordination in green supply chain management. *Journal of the Operational Research Society*, *64*(3), 336-351.

Wang, J. and Chen, M. (2013). Remanufacturing process for used automotive electronic control components in China. *Journal of Remanufacturing*, *3*(9), 1–17.

Wang, Y., Chang, X., Chen, Z., Zhong, Y. and Fan, T. (2014). Impact of subsidy policies on recycling and remanufacturing using system dynamics methodology: A case of auto parts in China. *Journal of Cleaner Production*, *74*, 161–171.

Wu, C. (2012). Price and service competition between new and remanufactured products in a two-echelon supply chain. *International Journal of Production Economics*, *140*(1), 496–507.