**Word Count: 9945**

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**Suspected Content**

Pricing Decision

for New and Remanufactured Product in a Closed-loop Supply Chain 2 with Separate Sales-channel

Abstract Remanufacturing is one of the recovery 43

processes that transforms

a used product into aâ€œlike-newâ€  product, 76

and usually comes with similar warranty to the new product. Many manufacturers have concerns that remanufacturing might cannibalize the sales of the new product. Recent development shows an increasing trend in selling products through non-traditional channels such as manufacturerâ€™s direct channel or e-channel. We develop a

pricing decision model for short life-cycle product in a closed-loop supply chain 38

that consists of manufacturer, retailer, and collector. New product is sold via traditional retail store and remanufactured product is sold via manufacturerâ€™s direct channel. We introduce two scaling factors; the first represents customerâ€™s acceptance towards buying remanufactured product (reman-acceptance), and the second represents customerâ€™s preference to buy remanufactured product via direct channel (direct-channel-preference). The results show that implementing separate channel can improve the total supply chainâ€™s profit compared to the single-channel approach. We also find that both scaling factors influence pricing

decisions and the profits of the supply chain members. 27

Keywords: pricing; remanufacturing; separate sales-channel; short life-cycle product.

1. Introduction The rapid development in science and technology 64

has led to faster innovation speed which brings much excitement to the society but poses challenges to the supply chain as the life cycle of the technology-based productsâ€™ becomes shorter ( Helo, 2004; Lebreton and Tuma, 2006; Hsueh, 2011). In technology-based commodities such as mobile phones and computers, there is also an increased obsolescence in productâ€™s function and desirability ( Packard, 2011) that forces the earlier product generation to become obsolete faster. This has led to the disposal of an outdated product at its end-of-use even when it is still in a good condition. Therefore, the short life-cycle products contribute significantly to the amount of waste going back to the mother earth. Remanufacturing is one option to manage products at the end-of-use phase, by transforming a used product into one with â€œlike-newâ€  condition. It includes the process of recapturing the value added to the material during the manufacturing process ( Lund and Hauser, 2010; Charter and Gray, 2008). Several studies have shown that remanufacturing is a recovery process that provides an opportunity for supporting the environmental awareness and complying to waste/ take-back legislation while maintaining profitability ( Guide &

Wassenhove, 2001; Kerr and Ryan,

2001; Savaskan et al., 2004 ; Ferguson & Toktay, 2006 ; Kaebernick et al., 2006; Geyer et al., 2007; Lee et al., 2010). When a 36

manufacturer also operates remanufacturing in addition to its regular production, the complexity

of the supply chain management would increase. The 3

firm has to deal with the reverse channel

of the supply chain in addition to the 59

forward channel and integrates the two to form what is now commonly referred to as closed-loop supply chain (CLSC). There are at least two important issues when a company sells both new and remanufactured products. For abbreviation remanufactured product is referred as reman product throughout the paper. First is the issue of pricing and the second is the issue of sales channels. The question of pricing would arise once a company sells both new and reman product simultaneously. While the reman product are technically functioning as good as new, it may be sensible to differentiate the price of the two. In such as case a follow up question emerges, i.e., how much different the price should be? An appropriate pricing strategy is important to address the concern of cannibalization toward the sales of new product ( Atasu et al., 2010) and the issues related to 3 market expansion effect (Souza, 2013). Few authors have published works that address pricing decisions in remanufacturing context, where some of them will be outlined here. Qiaolun

et al., (2008) develop a model to 1

obtain the optimal collecting price, the optimal wholesale price and the optimal retail price 11

in a CLSC. Two different models were compared and decision on who has to collect used products was recommended. Wei & Zhao (2011) develop an optimal pricing model in a CLSC system considering retail competition. The author use fuzzy and game theory to explore the wholesale price, retail price, and remanufacturing rate. Other authors such as Ferrer & Swaminathan, 2006, Souza, 2009; Lund & Hauser, 2009; Guide & Li; 2010, Shi et al., 2011; Subramanian & Subramanyam, 2011; Chen & Chang, 2013; Gan et al., 2015 also address pricing issues in a CLSC. However, most these publications only consider a single sales channel, typically â€œthe brick and mortarâ€ retail stores and neglect the fact, as argued by Atasu et al. (2010), that the pricing strategy for new and reman product should focus on market segmentation. The same question will arise in relation to sales channeling. Would the company use the same or different sales channels? Recent development shows that there is an increasing trend of companies selling products through non-traditional channels such as manufacturerâ€™s direct channel (e.g. factory outlet or warehouse stores) and e-channel (online stores). Dell computer sells its reman product via online channel called â€œDell Outletâ€ (Kumar and Craig, 2007) , while offers the new product via both retail and online stores. Similarly, Hewlett-Packard (HP) also sells the remanufactured computers in HPâ€™s online outlet store and customer cannot buy it in the retail store such as Best Buy, as revealed by Souza (2009). With the fast growth in the 4 internet usage, manufacturers sell products to the consumers

not only through traditional retail but also through the internet channel. 51

Sony, Samsung, IBM, and Apple also operate such dual- channel (Chen and Ku, 2013; Ding et al., 2016 ). These pricing and channeling issues in remanufacturing context are interdependent as the decision of product price would be affected by the sales channel used. Some authors have addressed pricing strategy within dual channel supply chain, but mostly for forward supply chain only. Huang & Swaminathan (2009) develop a model of

pricing strategy in a dual channel supply chain 1

assuming demand is deterministic but affected by the price offered. Chen

et al., (2013) study the pricing issue in a dual channel supply chain 2

where products are substitutable. Other authors such as Cai

et al., 2009; Dan et al., 2012; Zhang et al., 2012; Chen and Ku, 2013; 10

Hsiao and Chen, 2014; and Saha, 2016 also address pricing issues

in dual channel supply chain, but all of 39

these only focus on forward

supply chain. On the other hand, there are 3

several studies on CLSC that used on dual-channel in collecting used products ( Huang, et al., 2013; Hong et al., 2013) or in selling reman product ( Xu and Wu, 2012; Xiong and Yan, 2016 ). These works however, only consider the reverse supply chain. Many of the above mentioned references also treat both the new and reman product as being equal and given the same price.

To the best of our knowledge there is virtually no study 25 that addresses pricing strategy for both new and reman products that use dual sales channel in an integrated CLSC. Since reman product is often perceived as having lower quality compared to the new one, customerâ€™s willingness-to-pay is likely to be different towards new and reman product ( Souza, 2009; Lund & Hauser, 2009 ; Guide & Li; 2010, Subramanian & Subramanyam, 2011; Chen & Chang, 2013 ), therefore it is necessary to accommodate the pricing differentiation into the model. In this study, the new and reman product are differentiated and sold via separate channel. The new product is sold via retail channel while the reman

product is sold via manufacturerâ€™s direct channel. This 8

study contributes to the pricing strategy by extending pricing decision in a CLSC using separate sales channels, which to the best of our knowledge has not been done before. There are two scaling factors that characterize the separate sales channel. The first is customer acceptance towards buying reman product, or reman-acceptance in short, to show customerâ€™s willingness to buy reman product. The second factor is the level of customer's preference to buy reman product via direct channel, or direct-channel-preference in short.

Based on the above observation and analysis of the research 25

gaps,

this study aims to address the following research questions, 61

i.e. (1) what is the effect of separating sales channel to the supply chainâ€™s profit? (2) how is the profit distribution among the supply chainâ€™s members? (3) how do the reman-acceptance level and direct-channel-preference level influence the optimum results?. To answer these questions,

a Stackelberg game is applied with manufacturer as the leader and 1

various scenarios are explored in relations to pricing of the reman product and

customerâ€™s willingness to pay. A numerical example is presented to explore the 11

pricing behavior under

different scenarios. The remainder of this paper is organized as follows. Literature review is described in section 2. Section 3 describes the 12

problem definition which includes the CLSC system, the supply chain members involved in the pricing decision, notations, and demand functions. The optimization 6 modeling, including the optimum results and discussions, is given

in section 4, followed by the numerical example in section 63

5. Conclusion and

directions for future research is given in Section 6. 2. Literature Review 48

During

the past two decades, closed-loop supply chain has gained considerable attention in industry as well as academia 44

( Guide and Wassenhove, 2009 ). A critical review of CLSC analytical research can be found in Atasu et al. (2008). The evolution of CLSC research is described in Guide and Wassenhove (2009) which shows a movement from focusing on remanufacturing operations to focusing on the business perspective i.e. profitable value recovery. Souza (2013) provides a basic modeling framework in CLSC and classifies research into strategic, tactical and operational issues. The most recent review is

Govindan et al. (2015) that shows a systematic classification of 2

past research in

reverse logistics and CLSC, and provides the future research avenues. 2

The subsequent review is provided with a focus

on pricing decision in a CLSC and dual-channel supply chain. 53

2.1. Pricing decision in a

closed-loop supply chain The closed-loop supply chain management involves reverse supply chain 20

which is relatively more complex than forward supply chain. One of the complicating factor is product return management, which is one of the three key activities in the reverse supply chain ( Guide and Wassenhove, **72**

2009), hence many researchers study the problem of pricing a used product (core) and find the optimal collection/ acquisition price under different setting. Liang et al. (2009) argue that pricing a core is analogous to pricing an option and coreâ€™s sales price follows 7 geometric Brownian motion. Pokharel and Liang (2012) consider a stochastic return quantity and quality in finding the optimal price and quantity of cores to be collected. Jena and Sarmah (2013) consider random cores demand and three schemes of collection i.e. direct collection by remanufacturer, indirect by retailer, and coordinated between remanufacturer and retailer. Xiong et al. (2013) also consider random demand and return, then add uncertainty in the quality of cores, with possibility of lost sales. From the supply chain perspective, several researchers consider not only the collection but also the distribution of reman product to customers. The pricing problem is now focusing on finding the optimal acquisition price and selling price of the reman product. Guide et al. (2003) investigate factors that influence the production planning and control in a CLSC with product recovery under several quality classes of cores, and further determine the optimal prices.

Bakal and Akcali (2006) consider the effect of random recovery yield **54**

of cores, and Li et al. (2009) extend the work by adding random demand into consideration. Vadde et al. (2006) consider products with gradual and sudden obsolescence and determines the

optimal selling price for the reman product. As for the **68**

pricing problem in product-recovery facility that delivers several types of output such as reman product, refurbished product, reusable product in various quality levels; the objective is to find the optimal prices for those outputs. Mitra (2007) considers two types of output i.e. reman product for quality-conscious buyer, and refurbished product for price-sensitive buyer. Vadde et al. (2011) extend the output type to include

as-is reusable, recyclable, poor-quality reusable, and poor-quality recyclable **47**

products. In this model, optimal acquisition price is also included. While the above mentioned literature focused on reverse supply chain, there are broad collection of studies that

consider both forward and reverse supply chain, hence the **75**

pricing problem involves new and recovered/ reman products. In some cases, new and reman products are considered fully substitutable and sold with the same price. Ferrer and Swaminathan (2006) consider multi-period scenario under monopoly and duopoly model with deterministic demand and finds optimal prices and quantities. Qiaolun et al. (2008) focus on decisions of the cores collection price, wholesale and retail prices for the CLSC, under three collection scenarios

i.e. manufacturer for collecting, retailer for collecting, and third-party for collecting. **24**

Shi et al. (2011) consider random demand and returns, and determines optimal prices for brand-new and reman products, as well as the acquisition price. Wei and Zhao (2011) consider fuzziness in demands, remanufacting cost and collection cost, with two competitive retailers, to find optimal wholesale and retail prices under centralized and decentralized decision scenarios.

Gao et al. (2016) explore the effect of different power structures i.e. manufacturer Stackelberg, vertical Nash, and retailer Stackelberg, and 40

consider price and effort dependent demand,

to investigate the optimal decisions of pricing, collection effort and sales effort under centralized and 2

decentralized scenarios. The other collection in the literature deals with differentiated new and reman products. Atasu

et al. (2008) investigate the optimal price and quatity of new and differentiated reman products 8

under two competitive manufacturers in two-period model, and incorporate the existence of green segment. Ferrer and Swaminathan (2010) consider monopoly 9 and duopoly under two-, multi-period, and infinite planning horizon in determining the optimal prices and quantities. Ovchinnikov (2011) sets a fixed

price for the new product and optimizes the price and quantity of reman product 55

while adding customerâ€™s switching behavior into the model. Wu (2012a) focuses on original equipment manufacturer (OEM) dilemma in

determining the level of interchangeability in the product design, 22

since it could lower the

remanufacturerâ€™s cost in cannibalizing the 22

product, despite the decrease in OEMâ€™s manufacturing cost. A two-period model is constructed to investigate OEMâ€™s product design decision and

both chain membersâ€™ competitive pricing strategies.

22

Wu (2012b) also conducts a parallel studies that considers the degree of disassemblability in OEMâ€™s product design. Chen and Chang (2013) consider multi-period dynamic pricing under constrained cores supply. The supply constraint is limited to the availability of end-of-use products in the previous period. This work investigates the pricing behavior overtime under several parameter setting i.e. market property, return rate, and the degree of substitutability between new and reman product.

Abbey et al. (2015) investigate the optimal pricing for new and reman product using a model of consumer preference based on 8

an empirical study, and come up with two segments i.e. new- product-only segment, and indifferent segment. The model considers the fraction of each segment, and willingness-to-pay function (WTP function) that is uniformly distributed across [0,1]. Several cases are explored ranging from simple monopolist to a more complex case that involves competing third-party remanufacturer. Gan et al. (2015) consider three members of supply chain i.e. manufacturer, retailer, and collector, in determining the optimal wholesale and retail prices for new and reman product, as well as the optimal acquisition price. The model is 10 constructed to incorporate the effect of speed of change-in-demand for

a short life-cycle product. Most of the 29

above mentioned papers that develop pricing models for new and reman products consider only the productsâ€™ optimal prices and overlook the pricing decision in the cores collection, except in Qiaolun et al. (2008) and Gan et al. (2015) . In this paper, all three prices are optimized under manufacturer Stackelberg, and all three

members of supply chain are involved in the 20

game i.e. a manufacturer (who also acts as remanufacturer), a retailer, and a collector. The differences between this study and Qiaolun et al. (2008) are (1) in their work, new and reman products are not differentiated, (2) they use single sales channel. Compared to the work in Gan et al. (2015) , the only difference is in the use of dual channel instead of single channel. An introduction of a second separate channel as an outlet for the reman product is an effort to focus on market segmentation ( Atasu et al. 2010 ), since reman product is often perceived to have lower quality ( Souza, 2009; Agrawal et al., 2015 ) and attracts low-end segment more than high-end segment ( Gan et al., 2014 ). 2.2. Pricing strategy in

dual-channel supply chain Pricing strategy for dual channel in supply chain has been studied 46

quite extensively. Most of the published works are dealing with single product that are sold in two different channels, namely traditional wall and brick retail stores, and manufacturerâ€™s direct channel via internet .

The literature consists of studies with focus on retail service, disruption, channel structure and selection, and channel coordination. Retail service in

dual-channel supply chain influences pricing decision 1

as discussed in Hua

et al. (2010), Dan et al. (2012), He et al. (2016), and Roy et al. 10

(2016). The impact of service quality, which is focused on

delivery lead time and customer acceptance of a direct channel, on the manufacturerâ€™s and retailerâ€™s pricing 16

decision, is analyzed in Hua et al. (2010).

Customer loyalty to the retail channel is introduced in 39

Dan et al. (2012), where the optimal decisions on retail services and selling prices are investigated under centralized and decentralized dual- channel supply chain. A manufacturer Stackelberg sequential game is applied to the 18

decentralized approach. It is shown

that retail services strongly affect manufacturerâ€™ s and retailerâ€™s pricing strategies and profits, 5

while the

degree of customer loyalty to the retail channel have significant effect to the retail services and pricing decisions. 5

He et al. (2016) indicate that consumer free riding occurs when consumers enjoy the retail service but makes purchases via e-tailer at a lower price. This behavior has an impact in increasing total carbon emissions across supply chain. Roy et al. (2016) incorporate retailerâ€™s service level and promotional effort into the pricing model under centralized and decentralized scenarios.

Pricing strategy in dual- channel supply chain 35

is also influenced by disruption in the demand and production activity. Huang S. et al. (2012) and Huang S.

et al. (2013) study the pricing and production problem 35

under demand and production costs disruption, respectively. The model is 42

each developed

to adjust the prices and production plan under the 42

respective disruptions in both centralized and decentralized settings. The findings show that optimal pricing decision are affected by the disruption with a certain threshold based on customer preference for the direct channel, but the optimal production plan has some robustness under disruptions. 12 Regarding the channel structure, there are many works that investigate the

impact of introducing a direct channel 7

as the second distribution

channel. Chiang et al. (2003) develop a 16

model that conceptualized the

impact of customer acceptance of a direct channel and the 37

use of direct marketing for controlling the strategic channel. 37

The finding shows that

direct marketing can mitigate the double marginalization. 21

Tsay and Agrawal (2004) study the implications of channel conflict 60 to the distribution strategy, and examines ways to adjust the manufacturer- retailer relationship. Chun et al. (2011) study

manufacturerâ€™s direct channelâ€™ s strategy to manage the **21**

differing needs on consumer segments based on customerâ€™s heterogeneity and service sensitivity.

Xu et al. (2012) extend the work in Chiang et al. (2003) by **50**

investigating the effect of

price and delivery lead time decisions to the channel configuration strategy. It is shown that channel structure selection depends on customer acceptance of the online channel and the cost parameters. **9**

Hsiao and Chen (2014) consider a case where not only manufacturer has the option to operate the internet channel, but also retailer, or both. Customers are classified into two segments, namely grocery shoppers and internet shoppers that represents customerâ€™s channel preference. There are three strategies considered in the pricing decisions, which are grocery encroachment strategy, channel separation strategy with interior optimum, and channel separation strategy with corner optimum solution. Xiao and Shi (2016) consider pricing and channel priority strategies in the presence of supply shortage due to a random production yield. The impact of channel coordination on is also examined, along with time sequence decisions i.e. ex-ante and ex-post production yield. Pricing decision in dual distribution channel is studied by

Cattani et al. (2006) , Huang and Swaminathan (2009) **21**

, Zhang

et al. (2012) , and Lu and Liu **9**

13 (2013). In a

scenario where a manufacturer opens a direct channel **1**

that competes

with the traditional channel, Cattani et al. (2006) find that equal-pricing or consistent-pricing strategy that optimizes profits for the manufacturer is also preferred by the retailer and customers. **7**

This strategy is applicable when the

internet channel is significantly less convenient than the traditional channel. 23

Huang and Swaminathan (2009) study the implications for pricing and profit when 1

introducing the internet channel when demand on a channel is affected by market potential, prices, and degree of substitution across channel. The degree of autonomy for internet channel is also investigated in the pricing strategy, by considering both monopoly and duopoly setting. Zhang

et al. (2012) and Lu and Liu (2013) 10

study

pricing decisions in a dual- channel system under different power structures, 2

which are

manufacturer Stackelberg, retailer Stackelberg, and vertical Nash. 65

Zhang et al. (2012) focus on duopoly manufacturer and retailer, considers the

effects of product substitutability and relative channel status on pricing decisions, 29

and finds

that no power structure is always the best for 52

all members, while Lu and Liu (2013) focus on customer acceptance of channels, determines a threshold where a

channel cannibalizes all retail sales and dominates the distribution system, 17

and

find that both supplier and retailer are worse off in the Nash game.

17

Ding et al. (2016) study a

hierarchical pricing decision on a dual distribution channel 1

under Stackelberg game, and find the optimal

wholesale price, retail price and direct channelâ€™ s selling price. 7

The

results show that operating dual- channel is optimal to the manufacturer under some conditions, and consistent pricing strategy and price-matching strategy may not always optimal for the manufacturer. 1

Contracts are commonly used to coordinate channels, which can improve the supply chainâ€™s profit and in several occasion it can reduce the

channel conflict within a dual-channel supply chain. 13

Cai et al. (2009) investigate the impact of simple price discount contracts and pricing scheme on the dual-channel competition. The finding shows that price discount 13

scheme outperforms the

non-contract scenarios, and consistent-pricing can decrease the channel conflict. 49

Bin

et al. (2010) discuss the joint decision on production and pricing using a 1

principle- agent method under information asymmetry, and design two type of contracts i.e. single contract and a menu of contracts. Chen J. et al. (2012) examine two coordination schemes

that can coordinate the dual-channel supply chain,

28

(1)

a manufacturerâ€™s contract with a wholesale price and a price for the direct channel, 34

and (2) a complementary agreement consists of

two- part tariff and a negotiated profit-sharing that 28

allows a win-win coordination. Chen and Ku (2013) explore the channel strategy by implementing two contracts i.e. the

wholesale-price- only contract for the retail channel, and the revenue-sharing contract for the internet channel. 33

Chen Y.C. et al. (2013) consider a retailer that sells

not only the manufacturerâ€™s product but also a substitute product made by another manufacturer. 14

It is shown that

improving brand loyalty is profitable for both the manufacturer and retailer. Also, increasing service level can mitigate the channel 14

conflict and increase manufacturerâ€™s profit. Saha (2016) considers channel structures with

a traditional retail channel and two manufacturer direct channels with and without consistent pricing. 6

It is shown

that under some conditions, the dual-channel 6

15 outperforms the single channel. Furthermore,

a coordination mechanism is developed that not only coordinates the dual-channel but also outperforms the non-cooperative single retail channel. 6

This proposed paper is incorporating the prominent factor found in the above literature of

dual-channel forward supply chain into the proposed model that 6

involves new and reman product. The corresponding factor is direct-channel preference, which is used to identify the market segmentation and the tendency to cross over channels. Channel separation discussed in Chun et al. (2011) and Hsiao and Chen (2014) is also considered in our model. Chun et al. (2011) identifies two segments i.e. service-sensitive customer and price-sensitive customer, while Hsiao and Chen (2014) defines two types of customers i.e. grocery shopper and internet shopper. However, in both models the offered product is identical, so there is no difference in the supply process. In our work, channel separation is used to identify high-end customers who normally buy new product, and low-end customers who prefer reman product with lower price. There is a need to consider the supply for the reman product, that is, used product collected from customers. Therefore, the pricing decision is not only involving manufacturer and retailer, but also collector. 2.3. Pricing strategy in dual-channel

closed-loop supply chain The study on dual -channel closed loop supply chain is quite limited. In the 41

reverse channel, research on sales return in dual channel is conducted by Widodo et al. (2010) , where financtial benefit is examined for two scenarios of returns i.e. common return and cross-channel, under sequential-pricing (Stackelberg) and simultaneous-pricing (Bertrand) game. The results show 16 that simultaneous process always performs better in terms of total channel profit. Huang et al. (2013) considers

dual recycling channel where retailer and third party competitively collect used products. 45

Both centralized and decentralized channel scenarios are analyzed to determine the optimal prices. Furthermore, the

competing intensity domain is characterized for which the dual channel outperforms the single channel. 19

Hong et al. (2013) also studies hybrid dual- channel collection 15

with three structures

i.e. manufacturer and retailer collect the used products, 15

manufacturer contracting the collection to a retailer and a third party, and manufacturer and third-party 4

collect. The

results show that the manufacturer and the retailer hybrid collection channel is the most effective reverse channel structure for the manufacturer. Recent studies also explore the 4

adoption of dual-channel for marketing reman product, as showed in Xu and Wu (2012) and Xiong and Yan (2016) . The first paper considers a separate role in selling reman product, direct selling on internet is managed by the manufacturer, and the retailer takes charge of retail channel. It further studies competition among manufacturer, retailer, and recycle enterprise over the product recycle task, and finds the optimum direct selling price, retail price and remanufacturing rate. The results show that direct selling has positive effect in expanding market, but has negative impact by attracting demand from retail market. The latter paper discusses the implication of channel structures for marketing reman product i.e. via manufacturerâ€™s

owned e-channel, or via third party. The 71

analysis shows that retailer is better of when manufacturer chooses its e-channel. He (2015) discusses dual supply channel in a CLSC where manufacturer receives components from reliable supplier and from recycle supplier who collects used product and remanufactures it into an equivalent component to the reliable 17 supplierâ€™s. The model considers centralized and decentralized CLSC and determines optimal production and acquisition price. The closest work to ours is in Jiang et al. (2010) that investigates

pricing strategy in a dual- channel supply chain system 19

with remanufacturing using an agent-based modeling to decide optimum quantities and prices.

The manufacturer sells new and reman products via retailer channel and direct internet channel. The 30

multi-agent supply chain is modeled in 30 manufacturer agent, retailer agent, customer agent, finance agent, learning agent, and business agent. The results show that introducing reman product and direct channel can improve the optimal profits. The model parameters observed are customer preference, direct channel cost, and remanufacturing cost. Our paper differs from Jiangâ€™s, we develop an analytical model that includes several parameters to demonstrate the system behavior, and the optimum is found based on the characteristics of the model designed, not based on simulation.

To summarize, this paper contributes to the literature in three ways. First, the 26

proposed model involves new and reman product that are sold in separate channels. Most of the literature considers direct channel as a second channel to distribute product to customer. In our work, direct channel is a mean to separate the market segments. The importance of market segmentation when offering both new and reman products has been argued in Atasu et al (2010) and Abbey et al. (2015) . Second, most of the available literature on pricing decision in CLSC with dual channel considers manufacturer and retailer, but not collector. In a CLSC, collection plays a significant role since it represents supply constraints. Unlike the forward supply chain where raw material is considered unconstrained, in a CLSC material is collected from returns 18 or used products. Third, we consider a short life-cycle product, where the demand is represented by a time dependent deterministic function to contain the short life cycle pattern. It is important since short life-cycle products contributes significantly in exhausting the landfill. 3. Problem Definition A

closed-loop supply chain consists of three members, namely a manufacturer, a retailer, and a collector. The closed-loop 12

is initiated by a manufacturer who makes new product that is sold

at a wholesale price ??? to the retailer. The new product 62

is then released to the market by the retailer at a retail price ??. After a certain period of time, some products reach their end-of- use and become the objects of used products collection. The used product would be acquired by the collector under a certain acquisition price, ??. We assume that the collector only collects used products that meet the required quality level for the remanufacturing process. Therefore, all collected returns are transferred to the manufacturer at a price ?? , as the input for remanufacturing process. The reman product is then sold via manufacturerâ€™s direct channel such as factory outlets or warehouse stores, at a price ??. The closed-loop separate channel system can be seen in Figure 1. Figure 1. The closed-loop separate channel system In this model we consider a single product with short life-cycle. After a certain period in the market the product will be obsolete in terms of function as well as desirability. Demand functions are time-dependent and linear in price which represent the short life-cycle pattern along the entire phases both for new and reman products. There are four time-frames considered in this model, as depicted in Figure 2. In the first interval [0, t1], only new product is offered to the market. In second and third intervals, i.e. [ t1, m] and [m, t3], both new and reman products are offered. The difference between the second and the third intervals is on the segments of life-cycle phases for both types. During the second interval, both new and reman products are at the introduction-growth-maturity phases. In the third interval, the new product has entered the decline phase while reman product has not. In the fourth interval [ t3, T], manufacturer has stopped producing new product and only offers reman product which is assumed to be on the decline phase. The functions that represent these demand patterns are shown in (Gan et al., 2015) . The demand potentials for new and reman product are the demand volumes accumulated over those four time-frames, excluding the effect of price sensitivity. The total demands can be constructed by considering demand potentials, price sensitivity, and cross-channel sensitivity. Since cross-channel is also followed by a switch in customerâ€™s choice from buying new product to remanufactured one, a parameter that represents the scaling factor for reman-acceptance is introduced in the model. These demand functions are similar to the ones in (Hsiao and Chen, 2014) . We apply two market segments based on Atasu et al. i.e. newness-conscious or high-end customers, and functionality-oriented or low-end customers (Atasu et al., 2010) . Let ? be the customerâ€™s valuation to the new product, Â· High-end customers would buy new product in retail stores when ? ? ?? Â· High-end customers would buy reman product in manufacturerâ€™s direct channel if ??? ? ?? and ??? ? ?? ? ? ? ?? Â· Low-end customers would buy reman product in

manufacturerâ€™s direct channel if ??? ? ?? and ??? ? ?? ? ? ? ?? We assume that 74

low-end customers

would not buy new product, because the price 43

of new product is most likely higher than the price of reman product ( Souza, 2009; Lund and Hauser, 2010; Guide and Li, 2010; Subramanian and Subramanyam, 2012 ), and it is beyond their willingness to pay. The scaling factor for reman product, ??, represents the devaluation of reman product in high-end customerâ€™s view, as a result of quality perception. Reman product is often perceived 21 to be inferior to new product; therefore it has lower value in consumerâ€™s willingness to pay (Souza, 2009; Agrawal et al., 2015 ). For example, let ?? ? 0.7, it means high-end customer values reman product 70% of the product valuation, and he/she would only buy it if the price offered ???? is lower than his/her valuation. Furthermore, when the utility of buying new product is higher ?? ? ?? ? ??? ? ???, customer would not buy reman product despite the positive utility ???? ? ???. Figure 2. Demand pattern of a product with gradual obsolescence, over time The scaling factor for direct-channel-preference, ??, represents the preference of low-end customers to purchase the reman product via direct channel. Customer tends to believe that factory outlet or warehouse stores operated directly by manufacturer would offer a lower price compared to the same product sold in a retail store, because of double marginalization. Therefore, customers who favor in functionality over newness would have higher preference when reman product is sold via direct channel. Moreover, the green segment customer would prefer to purchase reman product. They would find it easier and more convenient to locate the product when it is offered in a different sales channel. On the other hand, since new and reman products are not offered hand-in-hand on the same location, the chance of cannibalization is low. Customer who has the intention to buy a new product would proceed to a retail store, with a lower risk of switching to reman product. After incorporating the scaling factors, the demand function is constructed for both segments. The product is assumed to be of a high quality such that low-end customerâ€™s willingness to pay is lower than the

price of the new product. Therefore, demand for the new product 3 typically comes from high-end customers, while demand for the reman product would mostly come from low-end customers. There exists a channel interplay, where high-end customer might switch to buy reman product. On the other hand, we make an assumption that none of the low-end customer who decided to buy reman product would switch to buy new product, since it is priced higher than their valuation or willingness to pay. Demand of the new product can be expressed as ? ?12 ?? ? ?? ? ?? ??? ? 1 ? ?1 ? ; ?? ? ?1?? . â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦ (1a) ??= ? ??1?2 ??? ? ??? ? ; ?1?? ? ?? ? ?2?? . .â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦ (1b) ? 0 ; ?? ? ?2?? where ??? is the cumulative demand potential of new product during [0, t3] (see Fig.2). The condition where â€œ?? is zero when ?? ? ????â€  represents the absence of channel interplay from ?? to ??. The condition where â€œprice of new product becomes too high that high-end customer will not buy new productâ€  is implied in (1b), i.e. ??= ??; and ??= 0 when ??= ??. Demand function for reman product is ??? ??34 ??? ? ?2 ?12 ?1 ? ?1 ?1?? ; ?? ? ?1?? ? 1 ?? ?+ ?? ? ?? ?? ? â€¦â€¦â€¦â€¦ (2a) ??= ? ?? ??? ? ?2 ? ?34 ?? ? ; ?1?? ? ?? ? ?2?? â€¦â€¦â€¦â€¦ (2b) ? 0 ; ?? ? ?2?? where ??? is the cumulative demand potential of reman product during [ t1, T] as in Figure 2. The condition where ?? is zero when ?? ? ????, represents a condition where the price of reman product is too high, exceeding low-end customerâ€™s valuation or willingness to pay. The optimal prices are found by applying the Stackelberg pricing game. It is started with the

manufacturer as the leader, releasing the wholesale price and remanufactured productâ€™s price 5

(reman price). This information is then used by the retailer, along with observation to the market demand, to

decide the optimal retail price of the new product. Collector, on the 11

other hand, observes the demand of reman product and decides the optimal acquisition price. The

collected used products are then transferred to the manufacturer, who further decides the 57

wholesale prices for both

the new product sold to the retailer and for the 69

reman price sold via direct channel. 4. Optimization Modeling The optimization is carried out under

sequential Stackelberg game with manufacturer as the leader. The objective of the 5

pricing model is finding optimal prices that maximize profits. Since the demand functions are piecewise functions which are defined by different expressions at different interval, we need to consider the price decision for each interval. Four scenarios are introduced based on retailerâ€™s optimum retail price. 4.1.

Retailerâ€™s Optimization Retailer only sells new product, and the sales quantity follows ?? in equation (1). We have two intervals for reman price that determine the demand profile, which are ?? ? ???? and ???? ? ?? ? ????. Retailerâ€™s optimization will be conducted for these two intervals. 4.1.1. Retailerâ€™s optimization for ?? ? ???? This interval implies that the price of reman product sold via direct channel is lower than high-end customerâ€™s valuation. Hence, there would be a shift in high-end customerâ€™s preference. A customer who originally intends to buy new product, purchases reman product in the end. The new product demand follows (1a), and the retailerâ€™s optimization problem is Max ?? Î  ?= ????? ??? ? ?????????? ??? ? ??? ? â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦. (3)

It is obvious that Î ? is concave in 9

??, thus there exists

optimal retail price that maximizes the retailerâ€™s profit. Taking the 32

first derivative condition yields ??? ??? ??? ?? = ??? ? 2 ????????? ????????= 0 + ??âˆ—= ??????????????? ? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (4) Since ?? ? ???? then ?? ? ???????????????????? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (5) Inequality (5) puts a restriction on reman price

based on the manufacturerâ€™s initial released wholesale price and 31

customerâ€™s maximum willingness to pay. 4.1.2. Retailerâ€™s optimization for ???? ? ?? ? ???? Under this condition, the price of reman product is higher than high-end customerâ€™s valuation, so they would not be interested in purchasing reman product. On the other hand, reman price is still lower than low-end customerâ€™s valuation. Demand of new product follows (1b) and the retailerâ€™s profit function is Max ?? Î  ?= ????? ??? ? ?????? ? ???? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (6) Since Î ? is concave in ??, thus there exists

optimal retail price that maximizes the retailerâ€™s profit and the 32

first derivative condition is ?????? ?????????2??+ ????= 0 = ??âˆ—= ?????? ? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (7) This result is the same as the single channel approach in (Gan et al., 2015) , where channel interplay does not exist. In this model, we consider two separate channels with a possibility of channel interplay, but in the second interval of reman price, the channel interplay diminishes. This approach is called channel separation strategy (Hsiao and Chen, 2014) . Furthermore, applying the restriction on reman price based on interval in ?? gives ?? ????????? ? ?? ? ?? ????????? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (8) and therefore ???????????????????? ? ?? ????????? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (9) After determining optimal retail price based on two different intervals of reman price in demand function, we are able to find restriction for reman price

based on the manufacturerâ€™s initial released wholesale price and 31 customerâ€™s maximum willingness to pay. These restrictions further create four regions for reman price that leads to four scenarios, as seen on Figure 3. Â· Scenario I (switching scenario) : ?? ? ???????????????????? Demand of the new product follows (1a) and demand of the reman product follows (2a). Optimal retail price is (4). This scenario represents a condition where reman price is lower than high-end customersâ€™ valuation towards a reman product. Hence, there are customers who switch from buying new products to buying reman products. Â· Scenario II (borderline-switch scenario) : ???????????????????? ? ?? ? ?? ????????? This scenario uses the boundary value of reman price, ??= ????. In order to encourage channel separation, we use demand functions (1b) for new product and (2b) for reman product. This represent a condition where reman price is at the lowest value for channel separation because it is at the borderline between high-end customersâ€™ switching. The optimal retail price is the corner point ??âˆ—= ?? ? ? â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (10) Â· Scenario III (separation scenario) : ?? ????????? ? ?? ? ?? ????????? This scenario finds optimum reman price within interior points of ???? ? ?? ? ???? . Demand of the new product follows (1b) and demand of the reman product follows (2b). Optimal retail price is (7). In this scenario the reman price is higher than high-end customersâ€™ valuation, hence the channel separation is strongly supported. Â· Scenario IV (borderline-no-reman scenario) : ?? ? ?? ????????? This scenario uses the other boundary value of reman price, ?? ? ???? , where direct- channel-preference is low such that reman price is at the borderline of no demand situation. Demand of the new product follows (1b) and demand of the reman product follows (2b). The optimal retail price is ??âˆ— ? ???? â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (11) Figure 3. Reman price regions that lead to four scenarios 4.2. Collectorâ€™s Optimization In collectorâ€™s optimization we apply an increasing return function that depends on the acquisition price, similar to (Qiaolun et al., 2008). The return function is represented by Î˜???? ? ??????, where ? ? 0 is a constant coefficient, and ? âˆˆ ?0,1? is the exponent of the power function in return rate function, which determine the curveâ€™s steepness. This function indicates that collected returns are only a portion of new productâ€™s sales, and the portion (or return rate) increases as acquisition price increases. Therefore, the collector should determine optimal acquisition price that would be high enough to acquire the needed quantity of returns, yet not too high as it would reduce the collectorâ€™s profit. We use balanced quantity throughout the supply chain, so the collector only acquires as much as the demand of the reman product. We have made an assumption that the collector would only collect used product that meets the quality criteria for remanufacturing process. Another assumption is made for the number of remanufacturing process applied to a product. We assume that the used product collected should be originated from new product, which suggests only a single or one-time remanufacturing process for each product. A parameter is introduced here, ? , unit collecting cost. The optimization is carried out for all scenarios. 4.2.1. Scenario I: ?? ? ???????????????????? The collectorâ€™s optimization problem is Max ?? Î  ?= ???? ????? ??? ? ?????????? ??? ? ?? ? ?? â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (12) The collectorâ€™s profit function is concave and the optimum collecting price is ??âˆ—= ??(??????)?? â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (13) Applying balanced quantity yields ? ?? ???? ??? ? ?????+ ??? ?????????? ??????= ???? ????? ??? ? ?????????? â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (14) ? Substituting ?? with (13), we find ??âˆ—= ? ??? ???????????????????????âˆ—????????âˆ—????????????????? âˆ™ ??? + ? ? â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (15) ? ? with ?? as in (4). 4.2.2. Scenario II: ???????????????????? ? ?? ? ?? ????????? The collectorâ€™s optimization problem in this scenario is Max ?? Î  ?= ???? ????? ??? ? ?????? ? ?? ? ?? â€¦â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (16) The collectorâ€™s profit function is concave and the optimum collecting price is the

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same as (13). The optimal acquisition price in scenario II is the same as in scenario I, because the demand function does not have contribution is fulfilling the first derivative condition. Furthermore, applying balanced quantity gives ????? ??? ? ???? ???? ????? ??? ? ??? ?= â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (17) Substituting ?? with (13) and ?? with (10), we find 30 ? ??âˆ—= ? ?????????????????????????? âˆ™ ??? + ? ? ? â€¦â€¦â€¦â€¦â€¦â€¦.. (18) 4.2.3. Scenario III: ?? ????????? ? ?? ? ?? ????????? The collectorâ€™s optimization problem in this scenario is the same as scenario II, which is given in (16), so is the balanced quantity as in (17). Therefore the optimal acquisition price is (13). Substituting ?? with the optimum and ?? with (7), we get ? ??âˆ—= ???????????????????????? âˆ™ ??? + ? ? ? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (19) ? ? 4.2.4. Scenario IV: ?? ? ?? ????????? In the fourth scenario, the collectorâ€™s optimization problem is also the same as scenario II, which is given in (16), as well as the balanced quantity as in (17). Therefore the optimal acquisition price is (13), and by using ?? as in (11) we are able to express the transfer price as ? ??âˆ—= ???????? ?? âˆ™ ??? + ? ? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (20) 4.3. Manufacturerâ€™s Optimization The optimal prices determined by the retailer and the collector become inputs in manufacturerâ€™s optimization in order to maximize his/her profit. The optimization problem is Max ???, ?? Î  ?= ?????? ? ??? ? ???+ ????? ? ?? ? ??? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (21) where ??? is unit raw material cost for producing new product, ?? is

unit manufacturing cost for producing new product, and ?? is unit remanufacturing cost

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for producing and selling reman product in manufacturerâ€™s direct channel. 4.3.1. Scenario I: ?? ? ???????????????????? In manufacturerâ€™s optimization, reman price ?? is a decision variable, therefore it is necessary to impose its restriction on each scenario. The restrictions become the constraints to the optimization problem. The optimization problem in scenario I is then stated as follows: Max ???, ?? Î  ?= ????? ??? ? ???âˆ—??????? ???? ? ??? ? ???+ ? ?? ???? ??? ? ???? ??? ????âˆ—?????? ?+ ? ?????? ??? ? ??âˆ— ? ??? â€¦â€¦â€¦â€¦â€¦â€¦â€¦.. (22) subject to (1) Reman price restriction for scenario I: ?? ? ???????????????????? (2) Supply constraint: ??? ??? ? ???âˆ—??????? ? ???? ??? ? ?????+ ??? ????âˆ—?????? ? ?????? (3) Lower bound: ??? ? ???_??????? ; ?? ? ??_??????? ???_??????? and ??_??????? are the initial wholesale and reman price released to the retailer and collector. (4) Upper bound: ??? ? ?1 ? ?????+ ?? where ??âˆ— and ??âˆ— are expressions given in (4) and (15), respectively. This optimization problem is solved by computational approach because it becomes too complex for analytical approach and for finding closed-form solutions. We utilize Matlab for finding the solutions. 4.3.2. Scenario II: ???????????????????? ? ?? ? ?? ????????? In this scenario, we use demand functions (1b) for new product and (2b) for reman product, in order to encourage channel separation. Since in scenario II ??âˆ—= ??/??, the manufacturerâ€™s profit function becomes Î ?= ????? ??? ? ????? ???? ? ??? ? ???+ ????? ??? ? ????? ??? ? ??âˆ— ? ??? It is obvious that the optimization process would seek the largest possible value for ??? to maximize the profit function. Therefore, the optimum must occur on the boundary, i.e. ??= ???????????????????? The optimization problem in scenario II becomes Max ???, ?? Î  ?= ????? ??? ? ????? ???? ? ??? ? ???+ ????? ??? ? ????? ??? ? ?? âˆ— ? ??? â€¦â€¦â€¦â€¦â€¦â€¦â€¦ (23) subject to (1) Reman price restriction in scenario II that provide the largest ???: ??= ???????????????????? (2) Supply constraint: ??? ??? ? ????? ? ??? ??? ? ????? (3)

Upper bound: ??? ? ?? where ??âˆ— is the expression given in (18). Similar to scenario I, this optimization problem is solved by computational approach due to its complexity 4.3.3. Scenario III: ?? ????????? ? ?? ? ?? ????????? In scenario III, we use demand functions (1b) for new product and (2b) for reman product, and ??âˆ—= ??????. The optimization problem become ? Max ???, ?? Î  ?= ????? ???????? ???? ? ??? ? ???+ ????? ??? ? ????? ??? ? ??âˆ— ? ??? ? â€¦â€¦â€¦â€¦â€¦â€¦â€¦ (24) subject to (1) Reman price restriction for scenario III: ?? ???????? ? ?? ? ?? ???????? ? ? (2) Supply constraint: ??? ????????? ? ??? ??? ? ????? (3) Upper bound: ??? ? ?? where ??âˆ— is the expression given in (19). 4.3.4. Scenario IV: ?? ? ?? ????????? In this scenario, reman price is high but is still within customerâ€™s willingness to pay. The model also take demand functions (1b) for new product and (2b) for reman product. Since in scenario IV, ??âˆ—= ??/?? ,

the manufacturerâ€™s profit function becomes Î ?= ????? ??? ? ????? ???? ? ??? ? ???+ ????? ??? ? ????? ??? ? ??âˆ— ? ??? Since the profit function is linearly increasing in ???, the

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optimization process would seek the largest possible value for ??? to obtain maximum profit. Therefore, the optimum must occur on the boundary, i.e. ??= ?? ?????????. Supply constraint can be omitted because ????? ??? ? ????? ? ????? ??? ? ????? implies ??? ? ???, which is obviously always true. The optimization problem in scenario IV becomes Max ??? Î  ?= ? ?????????? ???????? ? ??? ? ???+ ??? ??? ???????? ? ??âˆ— ? ???? ? â€¦â€¦â€¦â€¦â€¦â€¦â€¦ (25) subject to upper bound: ??? ? ?? where ??âˆ— is the expression given in (20). 5. Numerical Example Let the demand-potentialâ€™s parameters for new product and reman product be the same as the numerical example in the single channel approach in (Gan et al., 2015). Selling horizon is one year and divided into four periods where t1=1, m=2, t3=3, and T=4 in trimester units. The unit raw material cost for new product crw=1500, unit manufacturing cost cm=1000, unit remanufacturing cost cr=800, and unit collecting cost c=100. Maximum price is Pm=12000. Price and costs are given in thousands rupiah. Return rate parameters are ? =0.01, and q=0.7. Reman-acceptance (??) and scaling factor for direct-channel-preference ( ??) for scenarios I, II, III, IV are (0.8, 0.9), (0.7 and 0.8), (0.6 and 0.8), and (0.5 and 0.6), respectively. Since manufacturerâ€™s optimization is solved using computational approach, we investigate the existence and uniqueness of the solution through plotting approach, which is shown in Figure 4 for various scenarios. x 106 10 Manufacturers profit function 8 Manufacturers profit 6 4 2 0 (I) 5000 pr 10000 1000 2000 3000 4000 5000 6000 7000 8000 9000 pnw Manufacturers profit function x 106 7 6 5 Manufacturers profit 4 3 2 1 0 (III) -1 10000 8000 6000 6000 8000 4000 2000 4000 pr pnw x 10 7 Manufacturers profit function 1 0.5 0 Manufacturers profit -0.5 -1 -1.5 -2 (II) (II) -2.5 0 1000 2000 3000 4000 5000 6000 7000 x 106 Manufacturerpsrprofit function 6 5.5 Manufacturers profit 5 4.5 (IV) 4 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 pnw Figure 4. Manufacturerâ€™s Profit Function for Scenarios I, II, III, IV The computational results are given in Table 1.

Manufacturerâ€™s profit is much higher than retailer in separate channel

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system, because she sells both new and reman products, while retailer only sells new product.

Scenario I Scenario II Scenario III Scenario IV

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Single channel (Gan et al., 2015) ?? 0.80 0.70 0.60 0.50 ?? 0.90 0.80 0.70 0.60 ?? 7,700.00 8,571.43 9,500.00 10,000.00 9,889.78 ?? 6,346.70 5,647.74 5,673.33 5,597.54 8,318.83 ??? 7,120.05 6,888.65 6,911.08 6,658.48 7,018.45 ?? 729.03 366.10 389.80 248.25 422.04 ?? 1,870.49 989.10 1,046.67 702.89 1,124.96 Î ? 4,948,745.78 4,090,846.09 3,291,706.88 2,714,894.15 2,391,233.07 Î ? 505,607.36 961,102.81 1,078,173.11 1,113,281.64 1,246,142.45 Î ? 205,065.44 186,107.37 150,977.65 56,087.71 145,869.03 Total profit 5,659,418.58 5,238,056.27 4,520,857.64 3,884,263.50 3,783,244.55 ?? 871.81 571.14 416.46 333.17 351.53 ?? 196.90 390.67 308.02 211.20 150.73 Table 1. Numerical example for various scenarios From the results in Table 1 we are able to show that applying separate channel can improve the total supply chain profit, compared to the model with single-channel approach (Gan et al., 2015). In the single-channel model, the optimum reman productâ€™s price is quite high because the product is offered through the same channel as new product, i.e. retail store. Therefore, double marginalization exists and it pulls the reman productâ€™s price up and decreases the demand. The scaling factor that represents reman-acceptance, ?? , significantly influence pricing decisions and the

profits of the supply chain members. It can be 15

observed that lower reman- acceptance leads to higher retail price. This is understandable because high-end customer is more reluctant to purchase reman product (Atasu et al., 2010) , and the retailer responds to it by increasing the retail price. However, higher retail price would decrease new productâ€™s demand. Even though

retailerâ€™s profit is improving, manufacturerâ€™s profit is hurt by the 56

small quantity of new product. Despite the potential profit gain that comes from reman product, manufacturer must consider the supply constraint that puts a limitation to reman quantity. When reman-acceptance is high, the optimization would likely fall into the first scenario, under which the best performance in terms of total

supply chainâ€™s profit is demonstrated. In 3

fact, manufacturer receives the most benefit from this scenario, but retailer does not. As reman- acceptance gets higher, the chance of high-end customer switches from new to reman is also increasing. Retailer responds to it by lowering the retail price, to attract more high-end customer, and deter switching. However, as the Stackelberg leader, manufacturer optimizes her profit after receiving

retailerâ€™s pricing decision. Manufacturer finds optimal reman price that 67

is higher than the initial reman price released to retailer. Therefore, the demand decreases for reman product but increases for new product. Since retailer has already priced the new product relatively low, her profit is relatively low, even though it is better than the initial condition when new productâ€™s demand is low. Collector can also benefit from this scenario, but not in a consistent way. In this scenario, demand for reman product is high during retailerâ€™s optimization. Consequently, it is responded by high acquisition price, followed by high transfer price. Even though the first scenario performs best, it has a limitation. If reman-acceptance is very high, the reman productâ€™s demand can be too high that the collector cannot acquire enough used product for remanufacturing process due to the supply constraint. This is a limitation to our model. Therefore, it is our intention to further explore a pricing strategy that includes green 37 segment consideration, where reman price can be set higher than that of the new product; and a condition where there is a switch from reman to the new product. Scenarios II, III, and IV support channel separation strategy, where the effect of channel interplay is minimized. Scenario II is implemented when reman price lies at the borderline of switching from new to reman. When reman price is quite high relatively to high-end customer, then channel separation is naturally formed, and this is captured in scenario III. Scenario IV is applied to a situation where both reman-acceptance and direct-channel-preference is low, while reman price is quite high but still at the borderline of no demand situation. The model would respond with pricing decision that placed new and reman products according to the channel selection. There is a threshold for reman-acceptance under which selling reman product is no longer profitable. The collectorâ€™s optimum result is not following reman-acceptance trend. As reman- acceptance decreases, acquisition price and collectorâ€™s profit changes inconclusively. Scenario I gives the best result to the collector. This can be explained by the high demand of reman product during retailerâ€™s optimization that is responded by collectorâ€™s decision to collect high amount of returns. The attempt to collect sufficient used product is achieved by putting a high acquisition price that would be interesting enough for customer to sell their end-of-use product. Consequently, higher acquisition price is followed by higher transfer price, hence higher collectorâ€™s profit. Scenario III is the most similar case to single channel model (Gan et al., 2015). In this model, even though

new and reman products are sold through the 8

same channel, but we did not consider cannibalization. The term cannibalization refers to a situation where a customer who initially 38 plans to buy a new product, but since reman product becomes more attractive then he/she ends up buying reman product. It usually is caused by the attractiveness of low price among low-end or functionality-oriented customer. In this separate channel system, scenario III is only applied when reman price is within a certain interval between high-end customerâ€™s valuation towards reman product, and willingness to pay of the low end customers. Scenario IV works best for the retailer because it is implemented on a situation where reman- acceptance is low. Therefore,

retailer can set a higher retail price. 3

Despite lower demand caused by high retail price,

retailerâ€™s profit is higher than the 3

other scenarios. The effect of scaling factor for direct-channel-preference ( ?? ) can also be investigated through the results in Table 1. Scenario IV would be effective on lower ??. In this case, retail price is high and reman price is low compared to scenarios I and III. Since the demand of new and reman product are also low, the total supply chainâ€™s profit is depleted. This is understandable because scenario IV is the strategy for a situation that is very close to no demand. However, collector suffers the most. When retailer can still benefit from high retail price despite low demand for the new product, manufacturer still gain revenue from selling both products, the collector is hurt by small quantity of reman productâ€™s demand as well as low reman price, which means low transfer price. When we focus on the effect of ?? within the same scenario, it can be observed that the lower ??, the reman price, acquisition price, and transfer price are getting lower, but retail price and wholesale price do not change. However, when we apply different scenario, lower ?? leads to higher retail price. We have shown that applying separate sales-channel system, where new and reman products are sold through different channel, can improve the total supply chainâ€™s profit. Since the 39 optimums in this model are influenced by the level of reman-acceptance and direct-channel- preference, managers should assess those parameters in order to apply the best scenario. The lower the reman-acceptance, the lower the manufacturerâ€™s profit. Therefore, manufacturer needs to improve his/her marketing strategy in order to increase reman-acceptance. Also, a decrease in direct-channel-preference would reduce manufacturerâ€™s and collectorâ€™s profit. Marketing strategy and joint promotion between manufacturer and collector can increase direct- channel-preference. This is possible for example by offering trade-in program or rebate for customer who returns their end-of-use product in manufacturerâ€™s direct channel. 6. Conclusion and Future Research Pricing decision for new and differentiated reman product

in a closed-loop supply chain with separate sales channel 2

has been presented in this paper. We develop the pricing model under four scenarios with respect to the reman price and evaluate two parameters, namely reman- acceptance (??) which represents the willingness for high-end customers to switch purchases from new to reman products and direct-channel-preference ( ?? ) which represents the willingness of customers to purchase reman products offered through direct channels. The models enrich the literature on pricing decisions in the CLSC where channel separation for new and reman products is introduced. This proposed model is the first that implements separate sales channel and differentiates prices for new and reman products. Our numerical experiments demonstrate a number of important observations. First, the separate sales channel results in higher total supply chainâ€™s profit compared to the single- channel approach. This implies that, in a situation where manufacturer is capable of operating 40 a direct channel, it is advisable to sell new and reman product via different channels in order to target the right segment in each channel. This way, market segmentation is recognizable to address the managers concern that lower priced reman product could

cannibalize the sales of the new product 66

( Atasu

et al, 2010 ). Second, the best scenario for the supply chain 3

does not necessarily be the best for every member. As we have pointed out in the discussion above, the highest total profit for the supply chain is achieved when scenario I is implemented, that is, when the high-end customers are willing to switch purchases from new to reman products. However, this highest total profit is at the expense of the retailer whose profit is worst. The increase in profit is very much pooled to the manufacturer. This implies the need for the supply chain to design an incentive mechanism to each member to ensure that the maximum profit is gained without making any party worse off. Third, as for the scaling factors, the reman- acceptance factor significantly influences pricing

decisions and the profits of the supply chain members. The 27

lower the reman-acceptance, the higher the retail price; hence new productâ€™s demand decreases and

manufacturerâ€™s profit decreases. The direct-channel- preference, on the 70

other hand, is most effective in borderline-no-reman scenario. The lower the direct-channel- preference, the lower reman, acquisition, and transfer price; but retail price and wholesale price do not change within the same scenario. Manufacturerâ€™s and collectorâ€™s profits decrease as direct-channel-preference gets lower. Since the optimums in this model are influenced by the level of reman-acceptance and direct-channel-preference, managers should assess those parameters in order to apply the best scenario. The lower the reman acceptance, the lower the manufacturerâ€™s profit. Therefore, manufacturer needs to improve its marketing strategy to increase reman-acceptance. Also, a 41 decrease in direct-channel-preference would decrease manufacturerâ€™s and collectorâ€™s profit. Marketing strategy and joint promotion between manufacturer and collector can increase direct- channel-preference, for example through trade-in program or rebate for customer who returns their end-of-use product and purchase reman products in manufacturerâ€™s direct channel. Pricing decision is obviously strategic in any business and it is even more important when companies offer both new and reman products. The issue of cannibalization and sufficiency of cores as input to reman process are among those things that need to get sufficient attention. There are a lot of follow up studies that emerge from this paper. First, we do not consider green segment in this paper. When reman price is quite high, the model leads to a no-demand situation. A future study that attempts to refine the demand function to incorporate those customer segments who are willing to purchase reman products even if they are priced highly would be desirable. Second, we assume balance quantity throughout the selling horizon, therefore the dynamic of productâ€™s quantity the inventory and salvage consequences, are not explored. Third, this model uses the assumption of deterministic demand, a deviation from reality where demand is normally following a random function. These limitations warrant the need for further studies in this important field. 42 2 5 8 11 14 19 20 22 23 24 25 26 27 28 29 31 32 33 34 35 36