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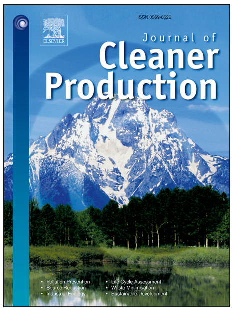
Published in:
Journal of Cleaner Production

DOI (link to publication from Publisher):
10.1016/j.jclepro.2019.06.071

Publication date:
2019

Document Version
Accepted author manuscript, peer reviewed version



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PII: S0959-6526(19)32024-4

DOI: https://doi.org/10.1016/j.jclepro.2019.06.071

Reference: JCLP 17240

To appear in: *Journal of Cleaner Production*

Received Date: 29 September 2018

Revised Date: 30 May 2019

Accepted Date: 7 June 2019

Exploring the intervention of intermediary in a green supply chain

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May 30, 2019

Abstract

In many countries, the contribution of unorganized or micro-retailers to the overall economy and sustainability is a topic of increasing importance. Although these retailers are commonly dependent on the intermediaries for trading, there is scarce literature addressing the influence of intermediaries in green supply chain practice. This study explores the repercussions of a dominant intermediary in a three-echelon green supply chain under price and greening level sensitive demand in both single and two-period setting. The results demonstrates that the manufacturer is able to sell maximum amount of products and the retailer receives higher profits if an intermediary dominates the market. A dominant intermediary can urge the manufacturer to promote products with a lower greening level. In such scenario, the unit R&D investment in producing green products is less, but each participant may receive higher profits. A sequential profit-sharing mechanism is proposed from the perspective of the manufacturer that can be employed under leadership of the wholesaler. Under this mechanism, the retailer can maintain strategic inventory, each member

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can receive higher profits, and most importantly, the manufacturer can promote products at highest greening level to achieve sustainability goals. If consumer takes into account the GL-price ratio, then two-period procurement planning always outperforms single period optimal decision under manufacturer-Stackelberg game. The insights can assist manufacturers to create a foundation for sustainable business practices.

Keywords: Green supply chain management; Strategic inventory; Profit-sharing; Stackelberg game; Three-echelon Supply chain.

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1. Introduction

Marketing activities in the presence of an intermediaries are common for manufacturers to reach geographically distinct markets or target businesses in third or fourth tier cities. Intermediaries such as wholesalers or stockists procure products from the manufacturer and re-sell these products to the consumer through retailers. The decision to include an intermediary in a distribution channel has distinct advantages. Intermediaries have more familiarity with local legislation, the local culture, and sometimes bear legal responsibility for the product (Welch et al. 2007, Cole and Aitken 2019). They can handle point of sale or after sales services through their own setup, conduct market research, and organize training program (Soundararajan et al. 2018). For example, the Dell Corporation successfully executed a multi-channel distribution approach involving intermediaries to reach a broad range of consumers (Simchi-Levi et al. 2013). Dominant intermediaries such as the Portland firm Crowd Supply help clients to raise start-up capital and become an established manufacturer (Wolf-Powers et al. 2017). The distribution channel structure in country like India is quite unique, as it contains nearly nine million outlets, mostly in unorganized traders such as grocers or kirana stores; general stores; specialized showrooms; mom and pop stores; as well as supermarkets; and hypermarkets. A FMCG company operating businesses across India has between 40 to 80 redistribution stockists (RSs). The RSs sells the product to between 100 to 450 wholesalers. Finally, RSs and wholesalers distribute product to retailers in the cities as well as rural parts (India - Distribution and Sales Channels, 2017). In Japan, intermediaries have become "a more integral part of their customers' operations"(Rawwas et al. 2008). In China, products need to pass through a multi-tier distribution system involving agents, distributors, wholesalers and sub-distributors before reaching the hands of the final consumers (Distribution in China, 2012). It is reported in Asialink Business (2018) that Australian manufacturers are also rely upon intermediaries to represent their businesses. Recently, Cole and Aitken (2019) conducted an empirical investigation on the role of intermediaries and reported that the intermediaries can "build links that deliver the needs of the buyer and supplier". Therefore, it is difficult to obtain the real consequences of the green supply chain (GSC) in the absence of intermediaries. But, analytical characteristics of the GSC structure beyond first-tier dyadic relationships are extremely limited. Specifically, the extant research has shed relatively little light on the influence of a dominant intermediary over GSC practice. To the best of the authors' knowledge, to date, the characteristics of a two-period three-echelon GSC have not been explored at a micro level. To pinpoint the influence of a dominant intermediary, this study analyzes the answer of the following research questions :

How does a dominant intermediary encroach upon GSC attributes? More specifically, to what extent does an intermediary influence pricing and optimal greening level (GL) decisions in a single- and two-period procurement setting? Does the presence of an intermediary encourage the retailer to maintain strategic inventory (SI)? If the intervention of an intermediary degrades the performance, what strategic measures the manufacturer should adopt to promote products at its higher GL? Which game structure and procurement strategy is more favorable to consumers?

This study contributes to our understanding on the influence of intermediaries on overall supply chain sustainability goal. Commonly, the presence of different types of intermediaries exist in distribution networks such as merchant wholesalers, speciality wholesalers; specific product wholesalers; drop ship wholesalers, etc. In this study, we do not make any assumption about the specific type of intermediaries, but consider an additional participants in middle tier, and explore the influence of this member on GSC practice. To consider various aspects, we formulate three echelon GSC models consisting of a manufacturer, a wholesaler, and a retailer under single and two-period setting; and explore characteristics of optimal decisions under manufacturer-Stackelberg (MS) and wholesaler-Stackelberg (WS) games. Note that is necessary to integrate the effect of GL to explore optimal decision due to the rapid growth of environmental awareness among consumers encourage. Therefore, the demand function is considered as a function of price and GL. In existing literature on GSC, optimal decision are explored mostly in a single period setting. Although in reality, the interaction continues for multiple number of periods and the retailer carry SI to gain wholesale price negotiation power (Anand et al. (2008). Therefore, it is necessary to compare the performance of two-period decision by benchmarking single-period model. Even though, researchers have shown that game structure has a deep impact on pricing and GL in GSC, they did not consider the influence of SI and dominant intermediary (Hou et al. 2017, Heydari at al. 2018). Because decision sequences of each GSC member are different under different channel leaderships, consequently optimal prices, GL and profits are also different. Therefore, it is necessary to explore the characteristics of GCS to obtain thorough understanding of how power structures affects sustainability goal. This study analyzes four GSC models and compares corresponding profits of each member, GL and per unit R&D invest cost of manufacturer to explore preferences of each member. Moreover, consumers can weigh the price and GL, consequently, optimal GL-price ratios are also compared to pinpoint consumer preferences. The outcomes of the study can assist manufacturers to execute sustainable business practices more efficiently. Our analyses show that retailers can enforce manufacturers to improve GL by maintaining SI in two period setting under both game structures. In addition, our results demonstrate that the wholesaler plays an imperative role in green product distribution. A dominant wholesaler's expectation to receive higher profits entice manufacturers to produce products at lower GL. Therefore, to eliminates inefficiency of the manufacturer, a sequential profit-sharing mechanism is proposed from the perspective of accomplishing a system-wide sustainability goal without violating the dynamics of the overall distribution system.

The remaining structure of this study is as follows: Section 1.1 reviews the related literature and identifies research gap. A detailed problem description under two game structures is presented in Section 2. The mathematical models for four scenarios are developed and corresponding characteristics of optimal decision are presented in Section 3. A comparative study is also performed in this section to explore pros and cons of two-period decision.

In Section 4, a profit sharing mechanism is proposed and its effectiveness is conferred with numerical illustration. A comprehensive view on managerial insight is provided in Section 5. Conclusion and future research direction are presented in final section.

1.1 Literature Review

In operations management, researchers explored the properties of GSC from various perspectives. We refer to the review articles of Sharma et al. (2017); de Oliveira et al. (2018); Gao et al. (2018), Fang and Zhang (2018), Koberg and Longoni (2019) for details about the various dimensions of GSC management practices, and provide a brief discussion on the analytical models formulated under price and GL sensitive demand. Ghosh and Shah (2012) investigated a two echelon GSC model under price and GL-sensitive demand and found that supply chain profits under MS game are lower compared to the vertical Nash game. Swami and Shah (2013) addressed GSC coordination issues where the retailer and manufacturer jointly invest to improve GL. The authors shown that the two-part tariff contract can able to reduce channel conflict. In a two echelon GSC, Ghosh and Shah (2015) proved that the manufacturer can produce products with a higher GL when a retailer offers cost-sharing contract. Zhu and He (2017) investigated two different types of green product design issues in a two-echelon supply chain. The authors found that government regulators should place emphasis on the price competition to improve GL. Yenipazarli (2017) stated that higher investment in green technology does not necessarily ensure a higher environmental performance, and price sensitivity of consumers is the key factor influencing manufacturer's decision. Basiri and Heydari (2017) formulated a GSC model under the retail price, GL, and sales effort sensitive demand. The authors found that the integrated supply chain might not lead to higher profits for every member. Ghosh et al. (2018) analyzed the impact of environmental regulations on the green product design. The authors established that consumers receive products with a higher GL if the government charges higher penalties or provides a higher subsidy. Song and Gao (2018) proved that a retailer-led revenue-sharing contract can improve the profits of the manufacturer, retailer, and GL, while a bargaining revenue sharing contract leads to lower amount of profits for the retailer. Patra (2018) studied a smartphone supply chain model under the different power structures, and concluded that greening investment efficiency, price and GL sensitivities are factors affecting optimal preference. Unlike the present study, all the cited articles explored the dyadic relationship among GSC members in a two-echelon setting and ignored the influence of intermediaries.

This study explores the optimal decisions in a three-echelon GSC under two game structures. According to Allaoui et al. (2019), "A supply chain is a complex system with many functions, activities and organizations" and it is necessary to explore the repercussions of intermediaries to realize factual characteristics in a multiple level supply chains. Gomez-Luciano et al. (2018) conducted an empirical study on food supply chain in the Dominican Republic. The authors found that mid-tier supply chain members can significantly improve distribution process that supports environmental planning, space utilization issues, product handling. Gadde (2004) claimed that it is necessary to include intermediaries to survive in the turbulent global retail sector and create a secondary resource layer in the distribution system. Wilson and Daniel (2007) noted that intermediaries are closer to consumers than manufacturers. Therefore, they have better perception to evaluate consumer choice. An innovative intermediary can be actively engaged in the product design and development for overall financial stability, assists the manufacturer to satisfy the requirements of diverse customer groups in different geographic territories (Dawson, 2007; Urakami and Wu, 2010). There are many analytical studies explore three-echelon chain, for instance, Ding and Chen (2008) studied a three-level supply chain under the stochastic customer demand. The authors employed a flexible return contract mechanism for achieving supply chain coordination. Seifert et al. (2012) studied the impact of sub-supply chain coordination problems under different scenarios and found that the retailer prefers to act alone rather than to coordinate with the manufacturer. Zhang and Liu (2013) analyzed a three-level green supply chain system to determine optimal retail prices under three different game structures by assuming GL as parameters. The authors used the revenue sharing mechanism for achieving supply chain coordination. Haidar et al.

(2014) considered a three-level supply chain to find optimal inventory and financial decisions under both the non-cooperative and cooperative environment. The authors proved that a higher return on the retailer's cash could lead to a higher retailer's order quantity. Leigh and Li (2015) conducted a case study to explore influence of large distributors on environmental sustainability in United Kingdom. The authors found that the distributor plays a critical role in a supply network in achieving overall sustainability goals. Saha (2015) discussed the impact of direct channel of a three-echelon dual-channel supply chain and found that the supply chain members always prefer inconsistent pricing in the presence of an intermediary. Giri et al. (2016) analyzed a single period three-echelon supply chain model under retail price and quality dependent demand. The authors explored the effect of a two-level retail fixed mark-up strategy from the perspective of supply chain coordination. Hou et al. (2017) derived Nash and Stackelberg equilibriums for a three-echelon decentralized supply chain. The authors found that a member's expected profit is negatively correlated with the bargaining power of its adjacent member. Heydari at al. (2018) studied a three-echelon dual channel green supply chain and explored characteristics of optimal decision under three scenarios, namely, distributor-led Stackelberg game, transitional triad and closed triad. The authors found that the GL under the transitional triad is as high as the closed triad. Lan et al. (2018) investigated the properties of a supply chain with a manufacturer, two distributors, and a retailer under a business-to-business setting. The authors reported that the manufacturer can receive higher profits in the presence of competition between distributors. It can be seen from above cited prior studies that the properties of a three-echelon GSC remain unexplored in a two period setting.

Inventory management and procurement decision are integral part of retailing (Zipkin 2000). However, the retailer can carry excess inventory as strategic purposes for ensuring a lower wholesale price in the forthcoming periods. As recognized by Keskinocak et al. (2008) and Anand et al. (2008), the retailer can enjoy strategic advantage under MS game framework when conventional reasons for carrying inventory, such as demand reducing logistics costs and supply risk, smoothing out seasonal fluctuations, do not exist. Martnez-de-Albniz and Simchi-Levi (2013) also reported that strategic use of inventory is practiced in the real world. An empirical research by Hartwig et al. (2015) shown that the retailer can significantly induce wholesale pricing behavior of upstream member by building up SI. Dey and Saha (2018) studied the impact of SI on GSC under MS game in a two-period setting, found that the retailer's strategic decision always encourages the manufacturer to produce products with higher GL. Guan et al. (2018) suggested that the retailer should withhold SI in order to receive higher profits. In this direction, the recent works by Moon et al. (2018); Roy et al. (2018); Nielsen and Saha (2018) are worth to be mentioned. The literature cited above acknowledges the usefulness of SI in a multi-period supply chain interactions under MS game only. However, two-period supply chain models in the absence of SI are studied in the context of electronic goods (Pan et al. 2009); short lifecycle products (Wang et al. 2015; Yang et al. 2016); or textile products (Maiti and Giri 2017;, Zhang and Zhang 2018). Most importantly, in all above cited literature, little attention is given towards exploring impact of SI in three-echelon GSC. If the retailer maintains SI and the intermediary dominates, then it is necessary to explore a countermeasure form the perspective of the manufacturer to mitigate the joint influence.

In this study, the pricing, GL, and R&D investment decision are explored under four different scenarios. From the literature review, one can identify the followings research gap: first, till today the influence of SI is not studied in a three echelon GSC environment. Therefore, the characteristics optimal decision of two-period procurement planning is required to explore and compared with conventional single period decision model. Second, one may find little literature pertaining to the comparative analytical analysis between optimal decision under two different game structures, especially when an intermediary dominates the market. This study will help practitioners to understand the pricing and GL decision under different power structure in a three echelon supply chain. Third, the influence of supply chain intermediaries in developing the bridge among other GSC members and establishing a sustainable supply chain are not fully evident in the existing literature(

Genovese et al. 2013, Villena and Gioia 2018). Nevertheless, if their presence does not add values to both financial and sustainability objectives, it is necessary to invent a policy so that the manufacturer can overcome the silent threat. Additionally, it is necessary to identify whether the distribution and power structures creates any impact on consumers preference.

2. Assumptions and notations

We consider a three-tier GSC in which a manufacturer(m) produces green products and sells to a retailer(r) through a wholesaler(w). We formulate a two-period model under two game structures, namely MS and WS games, and compare optimal decisions with a benchmark single-period decision model. Similar to Ghosh and Shah (2015), Song and Gao (2018), Dey et al. (2019), the demand functions at ith period (i=1,2), jth game structure (j=m, w), and kth procurement framework (k=t,s) are considered as follows:

$$D_i(p_{irj}^k, \theta_j^k) = a - bp_{irj}^k + \alpha\theta_j^k$$

where a, b, and α denote market potential, price, and GL sensitivities, respectively. Therefore, consumer demand is directly proportional GL (θ_j^k) and inversely proportional to retail price(p_{irj}^k).

To distinguish the outcomes in four different scenarios, namely Scenario jk, the following notations are used:

p_{imj}^k	wholesale price per unit determined by the manufacturer
p_{iwj}^k	wholesale price per unit determined by the wholesaler
p_{irj}^k	retail price per unit determined by the retailer
I_j^k	amount of SI ($I_j^k \geq 0$)
h	inventory holding cost of the retailer
π_{2xj}^k	profit of GSC members in second-period, x =m, w, r
π_{xj}^k	cumulative profit of GSC members in two consecutive periods, x =m, w, r
Q_j^k	cumulative sales volume in two periods

A new product manufacturing requires a considerable amount of resources for market research to analyze consumer preferences, the ramifications of the present technology, advertising and monitoring, product certification, etc. Therefore, manufacturers such as Apple, GE, Hewlett-Packard, Samsung Electronics, Godrej Appliances, Nestlé, Electrolux, etc. do not frequently introduce new variety of product. Because, there is a chance of the rejection of old product if a new one is introduced. For example, whenever Hewlett-Packard and Canon introduce the upgraded version of their desktop printers, the older models with fewer features become less desirable and eventually obsolete. Therefore, models are developed by assuming the GL remains unchanged in two consecutive periods(Dey et al. 2019).

To make the model feasible, we assume that prices of GSC members at each period satisfy the relations $p^k_{irj} > p^k_{iwj} > p^k_{imj}$, $i = 1, 2$, otherwise, the downstream members will be unwilling to sell products. Under MS game, the retailer and wholesaler respectively act as a follower in the games between the wholesaler and retailer, and the manufacturer and wholesaler. The manufacturer sets wholesale price and GL, then the wholesaler decides wholesale price. Finally, the retailer sets retail price and decides whether to build up SI. Under WS game, the retailer and manufacturer respectively act as a follower in the games between the wholesaler and retailer, and the manufacturer and wholesaler, respectively. The wholesaler decides price for the retailer, then the manufacturer sets wholesale price and GL. Finally, the retailer sets retail price and decides the volume of SI. Note that intermediaries acts as leader with respect to a three-tier supply chain consisting of a manufacturer under the retailer-Stackelberg game. However, under WS game, intermediaries have more price-setting power. In practice, wholesalers such as Li & Fung Limited, Eco Solutions, Bama Gruppen, Global Sources etc. have more power in some specialized sectors. Backward induction methods are used to derive the optimal decision under both games.

The manufacturer invests in R&D to produce green products. A larger investment is required for developing and integrating green technology to produce products at higher GL. The investment for the manufacturer in each period is considered as $\lambda\theta^2$, which implies a convex increasing cost in terms of greenness (Ghosh and Shah 2015), λ represents investment efficiency for the manufacturer. The manufacturer follows a lot-for-lot production policy (Hartwig et al. 2015; Guan et al. 2018; Dey and Saha 2018). The lead times between the manufacturer and wholesaler; and the wholesaler and retailer, are zero.

3. Game equilibrium analysis

We consider GSC models under both single and two-period setting. The manufacturer produces green product and sells to a wholesaler. Finally, a retailer procures from the wholesaler and sells to consumers in each period. The retailer has a downstream retail monopoly, and depends solely on the upstream wholesaler and manufacturer. We consider two-period model as our base model, and compare results with benchmark single-period decision model to explore pros and cons of two-period decision. The profit functions for the manufacturer, wholesaler, and retailer in two consecutive periods are as follows:

$$\pi^t_{2rj}(p^t_{2rj}) = (p^t_{2rj} - p^t_{2wj})D_2(p^t_{2rj}, \theta^t_j) + p^t_{2wj}I^t_j \tag{1}$$

$$\pi^t_{2wj}(p^t_{2wj}) = (p^t_{2wj} - p^t_{2mj})(D_2(p^t_{2rj}, \theta^t_j) - I^t_j) \tag{2}$$

$$\pi^t_{2mj}(p^t_{2mj}) = p^t_{2mj}(D_2(p^t_{2rj}, \theta^t_j) - I^t_j) - \lambda(\theta^t_j)^2 \tag{3}$$

$$\pi^t_{rj}(p^t_{1rj}, I^t_j) = (p^t_{1rj} - p^t_{1wj})D_1(p^t_{1rj}, \theta^t_j) - (p^t_{1wj} + h)I^t_j + \pi^t_{2rj}(\theta^t_j, I^t_j) \tag{4}$$

$$\pi^t_{wj}(p^t_{1wj}) = (p^t_{1wj} - p^t_{1mj})(D_1(p^t_{1rj}, \theta^t_j) + I^t_j) + \pi^t_{2wj}(\theta^t_j, I^t_j) \tag{5}$$

$$\pi^t_{mj}(p^t_{1mj}, \theta^t_j) = p^t_{1mj}(D_1(p^t_{1rj}, \theta^t_j) + I^t_j) - \lambda(\theta^t_j)^2 + \pi^t_{2mj}(\theta^t_j, I^t_j) \tag{6}$$

First, we explore optimal decision in Scenario MT. At the beginning of first period, the manufacturer determines wholesale price (p^t_{1mm}) and GL (θ^t_m), and posts those to the wholesaler. Then, the wholesaler sets wholesale price (p^t_{1wm}). Finally, the retailer sets retail price (p^t_{1rm}) and decides the volume of SI (I^t_j) to be carried in the next selling period. In the second period, the manufacturer sets wholesale price (p^t_{2mm}) and then the wholesaler sets wholesale price (p^t_{2wm}). Finally, the retailer sets retail price (p^t_{2rm}). In order to determine total profits, one needs to consider the sum of profits in two consecutive periods, because profit for each member in second period are function of GL and SI. The detail derivation of optimal decisions in Scenarios MT and WT are presented in

Appendices A and B, respectively. Profit functions for the manufacturer, wholesaler, and retailer under single-period setting are obtained as follows:

$$\pi^s_{2rj}(p^s_{2rj}) = (p^s_{2rj} - p^s_{2wj})D_2(p^s_{2rj}, \theta^s_j) \tag{7}$$

$$\pi^s_{2wj}(p^s_{2wj}) = (p^s_{2wj} - p^s_{2mj})D_2(p^s_{2rj}, \theta^s_j) \tag{8}$$

$$\pi^s_{2mj}(p^s_{2mj}, \theta^s_j) = p^s_{2mj}D_2(p^s_{2rj}, \theta^s_j) - \lambda(\theta^s_m)^2 \tag{9}$$

In the absence of SI, the optimal decision in each period is identical, the cumulative profits in two-period are $\pi^s_{rj} = 2\pi^s_{2rj}$, $\pi^s_{wj} = 2\pi^s_{2wj}$, and $\pi^s_{mj} = 2\pi^s_{2mj}$, respectively. Propositions 1 and 2 describe the optimal decisions in Scenarios MT and WT, respectively.

Proposition 1: Optimal decision in Scenario MT are obtained as follows:
$p^t_{1mm} = \frac{1674376a\lambda - 320h(2393b\lambda - 93\alpha^2)}{\Delta_1}$; $p^t_{1wm} = \frac{2535180a\lambda - 32h(36487b\lambda - 1427\alpha^2)}{\Delta_1}$; $p^t_{1rm} = \frac{2932042a\lambda - 583792bh\lambda - 4068h\alpha^2}{\Delta_1}$;
$I^t_m = \frac{4b(20121h\alpha^2 + 78089a\lambda - 288176bh\lambda)}{\Delta_1}$; $\theta^t_m = \frac{(247009a - 53800bh)\alpha}{\Delta_1}$;
$p^t_{2mm} = \frac{248(5452a\lambda + 4648bh\lambda - 433h\alpha^2)}{\Delta_1}$; $p^t_{2wm} = \frac{372(5452a\lambda + 4648bh\lambda - 433h\alpha^2)}{\Delta_1}$; $p^t_{2rm} = \frac{124(21601a + 6972bh)\lambda - 107438h\alpha^2}{\Delta_1}$;
$\pi^t_{rm} = \frac{4b(29791(3542327a^2 - 1776808abh + 133135 36b^2h^2)\lambda^2 + 961h(537633a - 60358472bh)\alpha^2\lambda + 2147829266h^2\alpha^4))}{\Delta_1^2}$;
$\pi^t_{wm} = \frac{7688b((109133473a^2 - 50085968abh + 51338880b^2h^2)\lambda^2 + 16h(11808a - 425585bh)\alpha^2\lambda + 251105h^2\alpha^4)}{\Delta_1^2}$;
$\pi^t_{mm} = \frac{494018a^2\lambda - 16bh(13450a\lambda - 14416bh\lambda + 961h\alpha^2)}{\Delta_1}$;
$Q^t_m = \frac{62b(16891a\lambda - 4528bh\lambda + 63h\alpha^2)}{\Delta_1}$, where $\Delta_1 = 3328904b\lambda - 247009\alpha^2$.

Proof. Please see Appendix A.

Proposition 2: Optimal decision in Scenario WT are obtained as follows:
$p^t_{1mw} = \frac{2(497a - 232bh)\lambda^2 + 16h\lambda\alpha^2}{\lambda\Delta_2}$; $p^t_{1ww} = \frac{62b(20445a - 9416bh)\lambda^2 - 497(225a - 88bh)\alpha^2\lambda + 1800h\alpha^4}{433b\lambda\Delta_2}$;
$p^t_{1rw} = \frac{124b(47291a - 9416bh)\lambda^2 - (438851a + 12984bh)\alpha^2\lambda + 7064h\alpha^4}{1732b\lambda\Delta_2}$
$I^t_w = \frac{248b(2519a - 9296bh)\lambda^2 + (23359a + 265336bh)\alpha^2\lambda - 376h\alpha^4}{1732\Delta_2}$; $\theta^t_w = \frac{(497a - 232bh)\alpha\lambda + 8h\alpha^3}{2\lambda\Delta_2}$;
$p^t_{2mw} = \frac{248b(1363a + 1162bh)\lambda^2 - 1988(15a + 23bh)\alpha^2\lambda + 480h\alpha^4}{433b\lambda\Delta_2}$;
$p^t_{2ww} = \frac{744b(1363a + 1162bh)\lambda^2 - 5964(15a + 23bh)\alpha^2\lambda + 1440h\alpha^4}{433b\lambda\Delta_2}$;
$p^t_{2rw} = \frac{248b(21601a + 6972bh)\lambda^2 - (394121a + 374800bh)\alpha^2\lambda + 6344h\alpha^4}{1732b\lambda\Delta_2}$;
$\pi^t_{rw} = \frac{b\Psi_1}{1499912b\lambda{\Delta_2}^2}$; $\pi^t_{ww} = \frac{247009a^2\lambda^2 - 16ah\lambda(497\alpha^2 + 6725b\lambda) + 16h^2(4\alpha^4 - 729b\alpha^2\lambda + 7208b^2\lambda^2)}{433\lambda\Delta_2}$;
$\pi^t_{mw} = \frac{\Psi_2}{374978b\lambda{\Delta_2}^2}$; $Q^t_w = \frac{112h\alpha^4 - 2(3479a + 1755bh)\alpha^2\lambda + 31b(16891a - 4528bh)\lambda^2}{433\lambda\Delta_2}$,
where $\Delta_2 = 3844b\lambda - 497\alpha^2$.

Proof. Please see Appendix B.

Note that, second order conditions of optimality holds and feasible solution exists in Scenarios MT and WT if $\Delta_i > 0, x = 1, 2$, respectively. By comparing optimal decisions, one can find that prices for each member are greater in the first period compared to the second period. The retailer needs to carry a high amount of SI under the WS game because the retailer can negotiate directly with the wholesaler (see Appendix C). The presence of the wholesaler cannot curtail the strategic advantage, the retailer till enforces the upstream members to reduce their respective wholesale prices in the second period by maintaining SI. The investment efficiency of the manufacturer is a key determinant for producing green products, because $\frac{\partial \theta_m^t}{\partial \lambda} = \frac{-3328904b(247009a-53800bh)\alpha}{\Delta_1^2} < 0$ and $\frac{\partial \theta_w^t}{\partial \lambda} = -\frac{2\alpha(961b(497a-232bh)\lambda^2+15376bh\alpha^2\lambda-994h\alpha^4)}{\lambda^2\Delta_2^2} < 0$, respectively. It is sensible that the manufacturer needs to be more efficient in producing green product to accomplish overall sustainability goals. The amount of SI are decreased in both game structures with respect to λ because $\frac{\partial I_m^t}{\partial \lambda} = -\frac{312356b(247009a-53800bh)\alpha^2}{\Delta_1^2} < 0$ and $\frac{\partial I_w^t}{\partial \lambda} = -\frac{\alpha^2(31b(3228015a-1014808bh)\lambda^2-722672bh\alpha^2\lambda+46718h\alpha^4)}{433\lambda^2\Delta_2^2} < 0$, respectively. Therefore, if manufacturers are efficient enough in R&D investment than they can curtail the strategic leverage of the retailer to some extent. By comparing optimal decisions in Scenarios MT and WT, the following theorem is proposed:

Theorem 1: In a two-period GSC,

(i) GL is greater under MS game

(ii) both the retailer and wholesaler receive higher profits under WS game

(iii) the manufacturer receives higher profits under MS game

Proof: See Appendix D.

It is somewhat intuitive that the manufacturer and wholesaler always receive higher profits under their respective leadership, Theorem 1 also demonstrates that fact. The retailer prefers high amount of SI under WS game, because the retailer able to negotiate directly with the wholesaler. Under MS game, due to the presence of wholesaler, the retailer cannot negotiate directly with the manufacturer which leads to a lower amount of SI compared to WS game. The manufacturer can invest more in producing green product at its highest GL due to higher price setting power, consequently consumers can receive products with higher GL under MS game. Theorem 1 also justifies this sensibility. Overall, the GL is reduced in a two-period setting if the wholesaler dominates the market, but consumers may need to pay less (See Appendix C).

Proposition 3: Optimal decision in Scenario MS are obtained as follows:

$$p^s_{1mm} = p^s_{2mm} = \frac{8a\lambda}{\Delta_3};\ p^s_{1wm} = p^s_{2wm} = \frac{12a\lambda}{\Delta_3};\ p^s_{1rm} = p^s_{2rm} = \frac{14a\lambda}{\Delta_3};\ \theta^s_m = \frac{a\alpha}{\Delta_3}$$

$$\pi^s_{rm} = \frac{8a^2b\lambda^2}{{\Delta_3}^2};\ \pi^s_{wm} = \frac{16a^2b\lambda^2}{{\Delta_3}^2};\ \pi^s_{mm} = \frac{2a^2\lambda}{\Delta_3};\ Q^s_m = \frac{4ab\lambda}{\Delta_3},\text{ where } \Delta_3 = 16b\lambda - \alpha^2.$$

Proposition 4: Optimal decision in Scenario WS are obtained as follows:

$$p^s_{1mw} = p^s_{2mw} = \frac{2a\lambda}{\Delta_4};\ p^s_{1ww} = p^s_{2ww} = \frac{a(12b\lambda-\alpha^2)}{2b\Delta_4};\ p^s_{1rw} = p^s_{2rw} = \frac{a(14b\lambda-\alpha^2)}{2b\Delta_4};\ \theta^s_w = \frac{a\alpha}{2\Delta_4};$$

$$\pi^s_{rw} = \frac{2a^2b\lambda^2}{{\Delta_4}^2};\ \pi^s_{ww} = \frac{a^2\lambda}{\Delta_4};\ \pi^s_{mw} = \frac{a^2\lambda}{2\Delta_4};\ Q^s_w = \frac{2ab\lambda}{\Delta_4},\text{ where } \Delta_4 = 8b\lambda - \alpha^2.$$

Note that, second order conditions of optimality holds and feasible solution exists in Scenarios MS and WS if $\Delta_i > 0, x = 3, 4$, respectively. Derivations of optimal decisions in Scenarios MS and WS are analogous to Scenarios MT and WT, respectively and hence omitted. By comparing prices of each member in Scenarios MS and WS, on can find that $p^s_{2mm} - p^s_{2mw} = \frac{2a\lambda(16b\lambda-3\alpha^2)}{\Delta_3\Delta_4}$, $p^s_{2wm} - p^s_{2ww} = \frac{a\alpha^2(4b\lambda-\alpha^2)}{2b\Delta_3\Delta_4}$, and $p^s_{2rm} - p^s_{2rw} = \frac{a\alpha^2(2b\lambda-\alpha^2)}{2b\Delta_3\Delta_4}$. Therefore, consumers can also receive product at a lower price under WS game. The profit ratios among the retailer, wholesaler and manufacturer under MS and WS games are $4b\lambda : 8b\lambda : 16b\lambda - \alpha^2$ and $4b\lambda : 2(8b\lambda - \alpha^2) : 8b\lambda - \alpha^2$, respectively. Therefore, the market potential does not make any impact on profit share. Under MS game, higher GL sensitivity affects the profit share of the manufacturer, where as it affects both the wholesaler and manufacturer under WS game. It demonstrates that consumers preference directly influence a dominant wholesaler. By comparing optimal decisions in Scenarios MS and WS, we propose the following theorem:

Theorem 2: In a single-period GSC

(i) GL is greater under WS game

(ii) both the retailer and wholesaler receive higher profits under WS game

(iii) the manufacturer receives higher profits under MS game

Proof: The following inequalities ensure the proof of the theorem:

$\theta^s_m - \theta^s_w = -\frac{a\alpha^3}{2\Delta_3\Delta_4} < 0; \pi^s_{rm} - \pi^s_{rw} = -\frac{2a^2b\alpha^2\lambda^2(32b\lambda-3\alpha^2)}{{\Delta_3}^2{\Delta_4}^2} < 0;$
$\pi^s_{wm} - \pi^{tp}_{ww} = -\frac{a^2\lambda(128b^2\lambda^2-16b\alpha^2\lambda+\alpha^4)}{{\Delta_3}^2\Delta_4} < 0; \pi^s_{mm} - \pi^s_{mw} = \frac{a^2\lambda(16b\lambda-3\alpha^2)}{2\Delta_3\Delta_4} > 0.$

Theorem is proved.

Theorems 1 and 2 reveal new dimensions of GSC research. First, most of the existing researchers explore GSC decisions under MS game in a single-period setting, however GL is maximum under WS game. Second, the impact of SI is explored in a two-tier supply chain only; however, GSC members, especially the manufacturer encounters an ironic situation: the manufacturer needs to compromise with GL due to presence of intermediaries. Downstream members are more closed to consumers, therefore, they can induce the manufacturer to produce greener products. A pragmatic supply chain framework contains many intermediaries. Perhaps, due to analytical tractability, GSC problems are commonly explored under a two echelon setting. The present study demonstrates that the presence of a dominance intermediary creates a dilemma. It justifies the necessity of exploring attributes of GSC under more pragmatic setting. To pinpoint the superiority of the two-period decision compared to single-period decision, we propose the following theorem:

Theorem 3:

(a) Under MS game, GL and profits are higher in a two-period setting

(b) Under WS game, GL is higher in a single-period setting, but GSC members can receive higher profits in a two-period setting.

Proof: See Appendix E.

The graphical representation of GLs, sales volume, and profits for each member in four scenarios are shown in Figures 1a-e. The following parameter values are used for illustration: $a = 1000$, $b = 50$, $h = 3$, $\alpha \in (10, 50)$, and $\lambda \in (5, 25)$, some of those are borrowed from the published works (Ghosh and Shah 2015; Dey and Saha 2018).

Insert Figures 1a-e

To consider the joint influences of consumer sensitivity on GL and efficiency of the manufacturer, three-dimensional figures are used. It is found that GLs decreased with the efficiency of the manufacturer. The result is noteworthy, because a dominant intermediary can also contribute in achieving the overall substantiality goal. Figure 1c demonstrates that the manufacturer may also receive higher profits in WS game. The results under MS game are partially consistent with Dey and Saha (2018), i.e. the manufacturer can receive profits in presence of SI. A contrasting result is observed under the WS game, profit-seeking motives of the retailer and wholesaler make an obstruction in achieving suitability goals. Surprisingly, sales volume in three scenarios satisfy $Q_w^t \geq Q_m^t \geq Q_w^s$ (See Appendix C). Therefore, a dominate intermediary can trade more products with a lower GL. The retailer can also earn higher profits if a market is dominated by intermediary. Next, we analyze the influence of a dominant intermediary on investment decision of the manufacturer.

3.1 Influence of intermediary on investment decision

Managing sustainable manufacturing operations is a business imperative. Manufacturers need to ensure that environmental improvements go hand in hand with profit-making competitiveness. However, higher R&D investment not only enhances unit cost, but can also reduce profit. We compute unit investment cost (UC) for manufacturers in Scenarios WS, WT, and MT as follows:

$UC_w^s = \frac{2\lambda(\theta_w^s)^2}{Q_w^s} = \frac{a\alpha^2}{4b\Delta_4}$

$UC_w^t = \frac{2\lambda(\theta_w^t)^2}{Q_w^t} = \frac{433\alpha^2(497a\lambda-8h(29b\lambda-\alpha^2))^2}{2(31b(16891a-4528bh)\lambda^2-2(3479a+1755bh)\alpha^2\lambda+112h\alpha^4)b\Delta_2}$

$UC_m^t = \frac{2\lambda(\theta_m^t)^2}{Q_m^t} = \frac{(247009a-53800bh)^2\alpha^2\lambda}{31b(16891a\lambda-4528bh\lambda+63h\alpha^2)\Delta_1}.$

Therefore, the differences among UCs are obtained as follows:

$UC_m^t - UC_w^s = \frac{\Upsilon}{124b(16891a\lambda - 4528bh\lambda + 63h\alpha^2)\Delta_1\Delta_4}$,

therefore, $UC_m^t \geq UC_w^s$ if $\Upsilon = \alpha^2(21a^2\lambda(9968868248b\lambda - 5462604035\alpha^2) - ah(383229792128b^2\lambda^2 - 65139164776b\alpha^2\lambda - 482408577\alpha^4) + 11577760000b^2h^2\lambda\Delta_4) \geq 0$. On simplification, if $h < \frac{a(482408577\alpha^4 + 65139164776b\alpha^2\lambda + \Delta_1\sqrt{31(201743104b^2\lambda^2 + 36544032b\alpha^2\lambda + 123039\alpha^4)} - 383229792128b^2\lambda^2}{23155520000b^2\lambda\Delta_4} = h_3(say)$

$UC_w^s - UC_w^t = \frac{\alpha^2\Upsilon_1}{4b(31b(16891a - 4528bh)\lambda^2 - 2(3479a + 1755bh)\alpha^2\lambda + 112h\alpha^4)\Delta_2\Delta_4} > 0$.

where $\Upsilon_1 = 7a^2\lambda(b\lambda(43074396b\lambda - 10439485\alpha^2) + 494018\alpha^4) + 2ah(b^2\lambda^2(529038816b\lambda - 99263764\alpha^2) + \alpha^4(4530715b\lambda - 27832\alpha^2)) - 55424bh^2(29b\lambda - \alpha^2)^2\Delta_4$.

Consequently, the following theorem is proposed:

Theorem 4: Unit investment costs for the manufacturer satisfy the relation $UC_m^t > UC_w^s > UC_w^t$ if $h < h_3$.

The graphical representation for UCs in three scenarios is shown in Figure 2. Although Scenario MS has been extensively studied by researchers, but we omitted this for further analysis because both GL and profits of each member are less compared to other four scenarios. The parameter values remain the same.

Insert Figure 2

Figure 2 also justifies the analytical findings. Comparing Figure 1a and 2, we can find that GL may lower in Scenario WT; consequently, unit investment cost is also less. However, the manufacturer can sell more products, and the retailer and wholesaler receive higher profits in Scenario WT. Therefore, in a green-sensitive market, wholesaler and retailer can jointly force the manufacturer to compromise with the substantiality goal for profits. The practical evidences in some countries also supports the outcome. For example, to produce in large scale or to satisfy the needs of a growing population, manufacturers sometimes promote food products at a lower quality in a price-sensitive market. This has led to food-borne diseases such as cholera, typhoid fever, food poisoning in Malaysia (Sharifa et al. 2013). However, due to food safety standards, such diseases have been almost eradicated in EU countries (Lamuka, 2014). Recently, the World Health Organization (2017) reported that "An estimated 1 in 10 medical products circulating in low- and middle-income countries are either substandard or falsified". The Uganda National Bureau of Standards (UNBS) reported that substandard products trading in areas bordering Kenya, South Sudan and Democratic Republic of the Congo are a severe cause for concern[1]. The products include sugar, bread, fruit juices, margarine, wines, beers, vodka, rice, yoghurt, packaged drinking water, baby diapers, dry cells, tiles, solar panels etc. Nigerian government was forced to introduce Product Authentication Mark (PAM) for all finished products to demonstrate their conformity to approved standards[2]. A recent study by Plambeck and Taylor (2016) also exposed an eye-opening glimpse about high-level manufacturing industry and reported that "testing by a regulator crowds out testing by competitors, and can reduce firms' efforts to comply with the product standard". One of the largest steel manufacturer, Kobe Steel, has acknowledged falsifying data about the quality of aluminum and copper it sold[3]. Our findings suggest that a dominant wholesaler adds more fuel in this regard, by trading with an inferior quality product.

Sensitivity analysis is carried out to identify consumers preference based on ratio of GL-retail price (RGP_{ij}^k). RGP_{ij}^k in four scenarios are obtained as follows:

$RGP_{1m}^t = \frac{\alpha(247009a-53800bh)}{62(47291a-9416bh)\lambda-4068h\alpha^2}$

$RGP_{1w}^t = \frac{866b\alpha((497a-232bh)\lambda+8h\alpha^2)}{124b(47291a-9416bh)\lambda^2-(438851a+12984bh)\alpha^2\lambda+7064h\alpha^4}$

$RGP_{2m}^t = \frac{(247009a-53800bh)\alpha}{124(21601a+6972bh)\lambda-107438h\alpha^2)}$

$RGP_{2w}^t = \frac{866b\alpha((497a-232bh)\lambda+8h\alpha^2)}{248b(21601a+6972bhr)\lambda^2-(394121a+374800bhr)\alpha^2\lambda+6344hr\alpha^4}$

$RGP_{1m}^s = RGP_{2m}^s = \frac{\alpha}{14\lambda}$

$RGP_{1w}^s = RGP_{2w}^s = \frac{b\alpha}{14b\lambda-\alpha^2}$

It is important to recognize from above expressions that the market potential and price sensitivity do not make any impact on the individual consumer preferences in Scenario MS. By comparing RGP_{ij}^k, the following theorem is proposed:

[1]observer.ug/news/headlines/57506-unbs-lists-10-most-inferior-commodities.html

[2]www.thisdaylive.com/index.php/2017/12/15/son-launches-pam-to-check-substandard-products/

[3]www.nytimes.com/2017/10/10/business/kobe-steel-japan.html

Theorem 5: GL-retail price ratio is always less in Scenario MS.

Proof: See Appendix F.

Insert Figures 3a-3d

One can observe that RGP_{ij} is increasing in a and α and decreasing in b and λ. Therefore, regardless of the game structures and procurement decision, the R&D investment efficiency is crucial factor influencing consumers gain. The consumers become better off when the manufacturer is efficient. Compared to single period procurement decision, two period procurement decision is more beneficial in perspective of consumers. What's more, the ratio is always lower in MS game with single period procurement decision, which is extensively studied in literature. Recall that, the GL also less in that scenario. To interpret this result, the retailer strategic decision to maintain SI stimulates the manufacturer to improve GL(see Appendix C), and the retailer cannot scale up the retail price in second period in presence of SI to safeguard potential market demand. In addition, consumers can implicitly get benefited from their environmental awareness, because of increasing nature of RGP. Overall, two period procurement decision not only makes consumers happy but improves individual profits. Therefore, a strategic measure is proposed in next section by which the retailer can maintain SI, dynamics of power structure is not violated, each GSC member can receive higher profits compared to the WS game, and most importantly, the manufacturer can trade with products at higher GL.

4. Profit-sharing mechanism to improve GL and profits

From the previous discussion, we can observe that GSC members may need to sacrifice the sustainability goal to receive higher profits. Eventually, the retailer's decision to maintain SI not only improves individual profit but also encourages the manufacturer to improve GL, especially when an intermediary dominates the GSC. To improve GL in the presence of SI, the manufacturer can employ a profit-sharing mechanism. In the literature, profit-sharing mechanisms are extensively discussed and employed to achieve supply chain coordination (Leng and Parlar 2009, Yan et al. 2018). Fu et al. (2018) mentioned that "the profit-sharing agreement approach is generally more beneficial to both parties involved, compared with the traditional wholesale price contract". However, our motive is different. Under this mechanism, members are not bound to comply with centralized decisions or it does not prevent a dominant wholesaler from making rational decisions. Manufacturers must use modern technology to intensify long-term sustainability goals and craft an objective for value creation. Therefore, the manufacturer should promote products at highest GL, i.e. GL achieved either in Scenario MT or WS or WT. Profit functions for the manufacturer, wholesaler, and retailer in two consecutive periods under profit-sharing mechanism are given below:

$$\pi^t_{2rp}(p^t_{2rp}) = (p^t_{2rp} - p^t_{2wm})(a - bp^k_{2rp} + \alpha\theta^*_p) + p^t_{2dm}I^t_p \tag{10}$$

$$\pi^t_{2wp}(p^t_{2dp}) = (p^t_{2wp} - p^t_{2mm})(a - bp^k_{2rp} + \alpha\theta^*_p - I^t_p) \tag{11}$$

$$\pi^t_{2mp}(p^t_{2mp}) = p^t_{2mp}(a - bp^k_{2rp} + \alpha\theta^*_p - I^t_p) - \lambda(\theta^*_p)^2 \tag{12}$$

$$\pi^t_{rp}(p^t_{1rp}, I^t_p) = (1-\phi)[(p^t_{1rp} - p^t_{1wp})(a - bp^k_{1rp} + \alpha\theta^*_p) - (h + p^t_{1wp})I^t_p + \pi^t_{2rp}(I^t_p)] \tag{13}$$

$$\pi^t_{wp}(p^t_{1wp}) = (1-\psi)[(p^t_{1wp} - p^t_{1mp})(a - bp^k_{1rp} + \alpha\theta^*_p + I^t_p) + \pi^t_{2wp}(I^t_p)] \tag{14}$$

$$\begin{aligned}\pi^t_{mp}(p^t_{1mp}) = {} & p^t_{1mm}(a - bp^k_{1rp} + \alpha\theta^*_p + I^t_p) - \lambda(\theta^t_m)^2 + \psi[(p^t_{1dp} - p^t_{1mp})(a - bp^k_{1rp} + \alpha\theta^*_p + I^t_p) \\ & + \pi^t_{2wp}(I^t_p)] + \phi[(p^t_{1rp} - p^t_{1wp})(a - bp^k_{1rp} + \alpha\theta^*_p) - (h + p^t_{1wp})I^t_p + \pi^t_{2rp}(I^t_p)]\end{aligned} \tag{15}$$

where $\theta^*_p \equiv \theta^t_m$ or θ^s_wor θ^t_w, $p = MT, WS, WT$. Under this mechanism, manufacturers sets GL first and then GSC members set their respective prices and the retailer decides volume of SI. In this way the manufacturer can promote green products without dominating the wholesaler's decision sequence. Under this mechanism, the retailer and wholesaler respectively share a percentage of their respective profits $\phi(0 \le \phi < 1)$ and $\psi(0 \le \psi < 1)$ with the manufacturer. We went on to verify the power of profit-sharing agreement in the context of accomplishing sustainability goal. The following proposition presents the optimal decision under profit-sharing mechanism.

Proposition 5: Optimal decision in profit-sharing mechanism are obtained as follows:
$p^t_{2mp} = \frac{4((1363-2M)(a+\alpha\theta^*_p)+(1162-M)bh)}{31b\Delta_5}$; $p^t_{2wp} = \frac{12((1363-2M)(a+\alpha\theta^*_p)+(1162-M)bh)}{31b\Delta_5}$;

$p_{2rp}^t = \frac{(43202-55M)(a+\alpha\theta_p^*)+12(1162-M)bh}{62b\Delta_5}$; $I_p^t = \frac{(5038+M)(a+\alpha\theta_p^*)-16(1162-M)bh}{62\Delta_5}$

$p_{1mp}^t = \frac{(a+\alpha\theta_p^*)(215201-548611\psi+25664\psi^2-465(433-802\psi)\phi)-8bh(12557-15345\phi-5\psi(9131-448\psi-6510\phi))}{961b(1-\psi)\Delta_5}$;

$p_{1wp}^t = \frac{15(a+\alpha\theta_p^*)(1363-64\psi-930\phi)-8bh(1177-64\psi-930\phi)}{31b\Delta_5}$;

$p_{1rp}^t = \frac{(a+\alpha\theta_p^*)(47291-1952\psi-28365\phi)-bh(9416-512\psi-7440\phi)}{62b\Delta_5}$;

$\pi_{rp}^t = \frac{(1-\phi)[((a+\alpha\theta_p^*)^2+bh(a+\alpha\theta_p^*)+8b^2h^2)\Gamma_1-465bh(11439a+32312bh+11439\alpha\theta_p^*)]}{124b{\Delta_5}^2}$

$\pi_{wp}^t = \frac{32(4(a+\alpha\theta_p^*)^2+b^2h^2)\Gamma_2-214303(a+\alpha\theta^*)^2-16(a+\alpha\theta_p^*)bh\Gamma_3}{1922b\Delta_5}$

$\pi_{mp}^t = \frac{(a+\alpha\theta_p^*)^2\Gamma_4-2bh(a+4bh+\alpha\theta_p^*)\Gamma_5-8b^2h^2\Gamma_6+7688b\lambda{\Delta_5}^2{\theta_p^*}^2}{3844b{\Delta_5}^2}$

where $\Delta_5 = 866 - 32\psi - 465\phi$; $M = 32\psi + 465\phi$;

$\Gamma_1 = 3542327+2048\psi^2-930\phi(1732-465\phi)-128\psi(866-465\phi)$; $\Gamma_2 = 3604-465\phi-\psi(898-32\psi-465\phi)$; $\Gamma_3 = (6725 + 7184\psi - 256\psi^2 + 3720(1-\psi)\phi)$; $\Gamma_4 = 218266946 + 262144\psi^3 - 22528\psi^2(624-341\phi) - 31\phi(3867943+930\phi(772-465\phi)) - 64\psi(2752815+62\phi(51866-14415\phi))$; $\Gamma_5 = 16(3130373-64\psi(97107+16\psi(429-8\psi)))-124(181399-32\psi(25933-968\psi))\phi+57660(193-496\psi)\phi^2-6702975\phi^3$; $\Gamma_6 = 62920688-32\psi(2948767-480\psi(429-8\psi))+124(126529+8\psi(93893-3568\psi))\phi-807240(47+31\psi)\phi^2+6702975\phi^3$.

Proof: See Appendix G.

Note that the dynamics of power structure are not violated and no one is bound to imply a centralized decision. The profit function for centralized GSC in each period is $\pi^c(p^c,\theta^c) = p^c(a-bp^c+c\theta^c)-\lambda(\theta^c)^2$ and corresponding optimal retail price, GL, profits in each period and sales volume are $p^c = \frac{2a\lambda}{4b\lambda-\alpha^2}$; $\theta^c = \frac{a\alpha}{4b\lambda-\alpha^2}$; $\pi^c = \frac{2a^2\lambda}{4b\lambda-\alpha^2}$; and $Q^c = \frac{4ab\lambda}{4b\lambda-\alpha^2}$, respectively. Under the centralized GSC, the objective of virtually integrated members is to maximize overall profits. If the manufacturer sets higher GL among three options based on parameters, then the demand for the product increased, as a consequence, the R&D investment is also increased. In such circumstances, the downstream GSC members can receive higher profits. Therefore, if the downstream GSC members share a percentage of their respective profits, then the manufacturer can compensate the rising R&D investment cost. The graphical representations of sales volume and profits of each member in four scenarios are shown in Figures 4a- 4d.

Insert Figures 4a - 4d

Recall that, the retailer and wholesaler receives higher profits in Scenario WT, but the manufacturer receives higher profits in Scenario MT. The above figures justify that all the members have an opportunity to receive higher profits compared to their optimal profits obtained under four scenarios. Moreover, the manufacturer may receive higher profits under WS game by promoting green products if the downstream GSC members are agreed to share a percentage of profit. Due to the complexity, it is difficult to give a simplified range of analytical region for profit sharing pair $\{\phi, \psi\}$(see Appendix G), because in the profit function their presence is cubic in nature. However, one may introduce 'franchise fee'(Modak et al. 2016) to obtain a larger feasible region or conventional supply chain coordination mechanisms where the supply chain members are somehow bound to employ centralized decision, although the optimal decision may fail to reflect pragmatic market dynamics (Katok and Wu 2009; Sluis and Giovanni 2018). Notably, from the perspective of achieving substantiality, one can acknowledge that if the manufacturer prefers to trade with greener products then a dominant intermediary or a strategic retailer cannot prevent.

5. Managerial implications

Due to globalization, the perpetual shift of power and leadership from manufacturer is observed at the micro-level (McDonald and Meldrum 2013). For example, despite the dominance of retailers in terms of sales, wholesalers still dominate buying from farmers before on-selling to a range of retail outlets for fresh fruit and vegetables to consumers, including supermarkets to meet expected retail demand, and managing quality and packaging requirements (FUTURE OF FRESH, 2018)[4]. Hindustan Unilever, a subsidiary of Unilever in India, successfully implemented "Project Shakti" with the potential involvement of wholesalers to promote products to micro-retailers (Rangan and Rajan 2007). According to Martins et al. (2017), wholesalers play an important role in the pharmaceutical industry. A report by Nikkei Asian review (2014) also supports the presence of dominant wholesalers in the drug market[5]. Even in FMCG, companies like Britannia or

[4]thesbhub.com.au/content/dam/anz-smallbusiness/downloads/HorticultureIrrigatedIndustriesReport.pdf

[5]https://asia.nikkei.com/Business/Little-known-Japanese-drug-wholesaler-dominates-Hokkaido-market

P&G use merchant wholesalers. These wholesalers have a greater control in the region in which they operate. They benefit, because they buy in bulk from the company and take charge of the risk they are facing. Commonly, a vegetable wholesaler buys products directly from the farm and stocks those at their own warehouse for future selling activity to the local retail outlets. Therefore, it is necessary to explore the influence of wholesalers on GSC. Several researchers empirically found that environmental and financial goals within organizations may create potential conflict (Sarkis et al. 2011), our study also support this. In a recent empirical study, Majumdar and Sinha (2018) identified some barriers such as "No specific environmental goals"; "Perception of out of responsibility zone" and: "Reluctance of support by supply chain partners" in the context of the Indian cotton industry. Similarly, Kaur et al. (2018) also mentioned that "Lack of eco-literacy amongst supply chain members" is a real barrier in context of Canadian manufacturing firms. Present study offers several practical recommendations for the manufacturer and downstream members to accomplish sustainability goals. First, as a stackelberg leader or producer, the manufacturer needs to take additional responsibility to shape overall sustainability goals because intermediary may want to promote products with lower GL. The manufacturer should not only be actively involved in promoting green products but also needs to conduct environment related awareness program among participants to drive the 'out of responsibility' perception to assist in transforming positive environmental attitudes. Notably, the bottleneck related to distribution network identified in the proposed study are different from the barriers exclusively highlighted in the empirical literature on GSC. Therefore, more empirical studies are necessary from the perspective of overall distribution structure of green products. Most of the analytical research works explored properties of GSC in single period setting under MS game. Our study illuminates how the game structures and procurement planning effect the consumer choice. But, ironically, it is found that GL-price ratio is less in Scenario MS compared to other three scenarios. Participants, powerful or powerless, should work together to select optimal procurement planning based on the market dynamics to safeguard consumer perspectives that yield financial as well as consumers benefit.

6. Summary and concluding remarks

Exploring correlations among environmental performance and green manufacturing to increase sales, sustainability, and enhance profit margins is an emerging research direction. Manufacturers need to set GL and wholesale price, while intermediaries such as wholesalers and retailers need to evaluate what products to endorse, while consumers take purchase decisions. However, we know little about how an intermediary influences the performance of GSC under price and GL-sensitive demand because extant analytical work on GSC in two-echelon setting fails to reflect the complexity of the real-world pragmatic business framework.

The strength of the present work is that it explores the properties of a three-echelon two-period GSC and pinpoints the influence of a dominant wholesaler under price-GL sensitive demand. Contributions of the present study are as follows: First, most of the existing literature discussed optimal decisions of three-echelon single-period supply chain under MS game. However, our study reveals that optimal decisions in single-period setting under MS game lead to a suboptimal GL. Additionally, the retailer always receives higher profits under WS game. Therefore, it will be admissible to explore properties of GSC beyond MS game setting. The results suggest that the downstream GSC member can insist the manufacturer to trade with products at higher GL. Second, in contrast to a single-period setting, a retailer's decisions to maintain SI in two-period setting encourages the manufacturer to trade with products at higher GL. Consequently, the MS game leads to optimal GL. Third, the retailer's decision to maintain SI encourages the manufacturer to produce products at its higher GL and each member may receive higher profits. In that respect, GSC models are required to study more under two- or multi-period settings. Fourth, researchers extensively discussed the influences of the government intervention such as tax or subsidy on GSC practice. Our study reveals that the government should also monitor the entire distribution process. If the market is dominated intermediary, then the likelihood of substandard product distribution can substantially increased. This may cause serious health and environmental concerns in the future. This finding is different from the ones commonly reported in the literature, i.e. financial constraints and lack of government regulations in the context of the manufacturing sector. Finally, our study reveals that a dominant intermediary cannot prevent the manufacturer in trading with products at higher GL. The manufacturer can employ a sequential profit-sharing mechanism proposed in this study in promoting green products without contravening marking market dynamics.

The concepts addressed in this study could also be advanced in several ways. One could extend the proposed model by incorporating sub-supply chain coordination problems, as seen in (Seifert et al. 2012) or explore the influence of supply chain coordination mechanisms such as revenue sharing contract, buyback contract, cost sharing contract, etc. One might expand this study by analyzing the impact of wholesaler's SI and explore characteristics of optimal decision under the Nash game or retailer-Stackelberg game. One may also add another degree of demand variation by incorporating impact of sales effort of GSC members in enhancing market demand or influence of government inventive or regulations under a three-echelon multi-period GSC model.

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Appendix A. Optimal decision in Scenario MT

The retailer second-period price is obtained by solving $\frac{d\pi^t_{2rm}}{dp^t_{2rm}} = 0$. On simplification, $p^t_{2rm}(p^t_{2wm}, \theta^t_m) = \frac{a+bp^t_{2wm}+\alpha\theta^t_m}{2b}$. The profit function of the retailer is concave because $\frac{d^2\pi^t_{2rm}}{{dp^t_{2rm}}^2} = -2b < 0$. Substituting p^t_{2rm} in Equation (2) and solving $\frac{d\pi^t_{2wm}}{dp^t_{2wm}} = 0$, wholesaler's price is obtained as $p^t_{2wm}(p^t_{2mm}, \theta^t_m) = \frac{a-2I^t_m+bp^t_{2mm}+\alpha\theta^t_m}{2b}$. The profit function is concave because $\frac{d^2\pi^t_{2wm}}{{dp^t_{2wm}}^2} = -b < 0$. Finally, price of the manufacturer is obtained by solving $\frac{d\pi^t_{2mm}}{dp^t_{2mm}} = 0$. On simplification, $p^t_{2mm}(\theta^t_m, I^t_m) = \frac{a-2I^t_m+\alpha\theta^t_m}{2b}$ and the profit function is concave because $\frac{d^2\pi^t_{2mm}}{{dp^t_{2mm}}^2} = \frac{-b}{2} < 0$.

Substituting the optimal response in Equation (4), the cumulative profit function for the retailer is obtained as follows:

$$\pi^t_{rm}(p^t_{1rm}, I^t_m) = p^t_{1rm}(a - bp^t_{1rm} + \alpha\theta^t_m) - p^t_{1wm}(a + I^t_m - bp^t_{1rm} + \alpha\theta^t_m) - hI^t_m$$
$$+\frac{a^2 + 60aI^t_m - 60{I^t_m}^2 + 2(a + 30I^t_m)\alpha\theta^t_m + \alpha^2{\theta^t_m}^2}{64b}$$

By solving $\frac{\partial\pi^t_{rm}}{\partial p^t_{1rm}} = 0$ and $\frac{\partial\pi^t_{rm}}{\partial I^t_m} = 0$ simultaneously, optimal response are obtained as follows:

$$p^t_{1rm}(p^t_{1wm}, \theta^t_m) = \frac{a+bp^t_{1wm}+\alpha\theta^t_m}{2b} \quad \text{and} \quad I^t_m(p^t_{1wm}, \theta^t_m) = \frac{15a-16b(h+p^t_{1wm})+15\alpha\theta^t_m}{30}$$

Because $\frac{\partial^2\pi^t_{rm}}{{\partial p^t_{1rm}}^2} = -2b < 0$ and $\frac{\partial^2\pi^t_{rm}}{\partial {p^t_{1rm}}^2} \times \frac{\partial^2\pi^t_{rm}}{\partial {I^t_m}^2} - \left(\frac{\partial^2\pi^t_{rm}}{\partial p^t_{1rm}\partial I^t_m}\right)^2 = \frac{15}{4} > 0$, the profit function for the retailer is concave. Substituting these values in Equation (5), the profit function for the wholesaler is obtained as follows:

$$\pi^t_{wm}(p^t_{1wm}) = \frac{8}{225}b(h + p^t_{1wm})^2 + \frac{1}{30}(p^t_{1wm} - p^t_{1mm})(30a - 16bh - 31bp^t_{1wm} + 30\alpha\theta^t_m)$$

By solving $\frac{d\pi^t_{wm}}{dp^t_{1wm}} = 0$, we obtained $p^t_{1wm}(p^t_{1mm}, \theta^t_m) = \frac{450a-208bh+465bp^t_{1mm}+450\alpha\theta^t_m}{898b}$. Because $\frac{d^2\pi^t_{wm}}{{dp^t_{1wm}}^2} = -\frac{449b}{225} < 0$, the profit function for the wholesaler is concave. Finally, the profit function for the manufacturer in Equation (6) is obtained as follows:

$$\pi^t_{mm}(p^t_{1mm},\theta^t_m) = \frac{1}{8064046}[14400a^2+b^2(33856h^2-191440hp^t_{1mm}-416113{p^t_{1mm}}^2)+14400\alpha^2{\theta^t_m}^2$$
$$+a(44160bh+418594bp^t_{1mm}+28800\alpha\theta^t_m)+2b\theta^t_m(22080h\alpha+209297p^t_{1mm}\alpha-8064046\theta^t_m\lambda)]$$

By solving $\frac{\partial\pi^t_{mm}}{\partial p^t_{1mm}}=0$ and $\frac{\partial\pi^t_{mm}}{\partial\theta^t_m}=0$ simultaneously, we obtain the GL and price for the manufacturer as presented in Proposition 1. The profit function for the manufacturer is also concave because $\frac{\partial^2\pi^t_{mm}}{\partial {p^t_{1mm}}^2}=-\frac{416113b}{403202}<0$ and $\frac{\partial^2\pi^t_{mm}}{\partial {p^t_{1mm}}^2}\times\frac{\partial^2\pi^t_{mm}}{\partial {\theta^t_m}^2}-\left(\frac{\partial^2\pi^t_{mm}}{\partial p^t_{1mm}\partial\theta^t_m}\right)^2=\frac{\Delta_1}{806404}>0$, where $\Delta_1=3328904b\lambda-247009\alpha^2>0$. Collectively, one can obtain optimal decision in Scenario MT as shown in Proposition-1.

Appendix B. Optimal decision in Scenario WT

To find the optimal decision in Scenario WT, we used transformation $m^k_{iww}=p^k_{iww}-p^k_{imw},(i=1,2)$ and $m^k_{irw}=p^k_{irw}-p^k_{iww},(i=1,2)$. By solving $\frac{d\pi^t_{2rw}}{dm^t_{2rw}}=0$, the profit margin of the retailer is obtained as, $m^t_{2rd}(p^t_{2mw},\theta^t_w)=\frac{a-b(p^t_{2dw}+m^t_{2ww})+\alpha\theta^t_w}{2b}$. The profit function of the retailer is concave because $\frac{d^2\pi^t_{2rw}}{d{m^t_{2rw}}^2}=-2b<0$. Using the value of m^t_{2rw} and solving $\frac{d\pi^t_{2mw}}{dp^t_{2mw}}=0$, the wholesale-price for the manufacturer in second period is obtained as $p^t_{2mw}(m^t_{2ww},\theta^t_w)=\frac{a-2I^t_w-bm^t_{2ww}+\alpha\theta^t_w}{2b}$. The profit function is concave because $\frac{d^2\pi^t_{2mw}}{d{p^t_{2mw}}^2}=-b<0$. Now substituting the response of the retailer and manufacturer, the wholesaler's profit margin for the second period is obtained by solving $\frac{d\pi^t_{2ww}}{dm^t_{2ww}}=0$. On simplification, $m^t_{2ww}(I^t_w,\theta^t_w)=\frac{a-2I^t_w+\alpha\theta^t_w}{2b}$. The profit function is also concave because $\frac{d^2\pi^t_{2ww}}{d{m^t_{2ww}}^2}=-\frac{b}{2}<0$.

Substituting the optimal responses obtained in the second period, the retailer's decision problem can be stated as:

$$\pi^t_{rw}=\frac{1}{64b}[a^2-60{I^t_w}^2-64b^2m^t_{1rw}(m^t_{1ww}+m^t_{1rw}+p^t_{1mw})+60I^t_w\alpha\theta^t_w+\alpha^2{\theta^t_w}^2$$
$$+2a(30I^t_w+32bm^t_{1rw}+\alpha\theta^t_w)+64b(m^t_{1rw}\alpha\theta^t_w-I^t_w(hr+m^t_{1ww}+p^t_{1mw}))]$$

By solving $\frac{\partial\pi^t_{rw}}{\partial m^t_{1rw}}=0$ and $\frac{\partial\pi^t_{rw}}{\partial I^t_w}=0$, one can obtain the profit margin and amount of SI as:

$m^t_{1rw}(p^t_{1mw},\theta^t_w)=\frac{a-b(p^t_{1mw}+m^t_{ww})+\alpha\theta^t_w}{2b}$ and $I^t_w(p^t_{1mw},\theta^t_w)=\frac{15a-16b(h+m^t_{1ww}+p^t_{1mw})+15\alpha\theta^t_w}{30}$

Because $\frac{\partial^2\pi^t_{rw}}{\partial {m^t_{1rw}}^2}=-2b<0$ and $\frac{\partial^2\pi^t_{rw}}{\partial {m^t_{1rw}}^2}\times\frac{\partial^2\pi^t_{rw}}{\partial {I^t_w}^2}-\left(\frac{\partial^2\pi^t_{rw}}{\partial m^t_{1rw}\partial I^t_w}\right)^2=\frac{15}{4}>0$, the profit function for the retailer is concave. Using these obtained responses, profit function for the manufacturers is obtained as follows:

$$\pi^t_{mw}=p^t_{1mw}(a+\alpha\theta^t_w)+\frac{8b(h+m^t_{1ww}+p^t_{1mw})^2}{225}+\frac{bp^t_{1mw}(16h+31(m^t_{1ww}+p^t_{1mw}))}{30}-2\lambda{\theta^t_w}^2$$

Solving $\frac{d\pi^t_{mw}}{dp^t_{1mw}}=0$ and $\frac{\partial\pi^t_{mw}}{\partial\theta^t_w}=0$ simultaneously, one can find the wholesale-price of the manufacturer and the GL for the first period as:

$p^t_{1mw}(m^t_{1ww})=\frac{2(450a-208bh-433bm^t_{1ww})\lambda}{1796b\lambda-225\alpha^2}$ and $\theta^t_w=\frac{(450a-208bh-433bm^t_{1ww})\alpha}{2(1796b\lambda-225\alpha^2)}$. The concavity condition holds because $\frac{\partial^2\pi^t_{mw}}{\partial {p^t_{1mw}}^2}=-4\lambda<0$ and $\frac{\partial^2\pi^t_{mw}}{\partial {p^t_{1mw}}^2}\times\frac{\partial^2\pi^t_{mw}}{\partial {\theta^t_w}^2}-\left(\frac{\partial^2\pi^t_{mw}}{\partial p^t_{1mdm}\partial\theta^t_w}\right)^2=\frac{1796b\lambda-225\alpha^2}{225}>0$.

Finally, the wholesaler's decision problem can be stated as::

$$\pi^t_{mw}=\frac{16b(h+m^t_{1ww})^2\alpha^2-900a^2\lambda+b(64h(13a-5bh)+4(433a-264bh)m^t_{1ww}-961b{m^t_{1ww}}^2)\lambda}{(3592b\lambda-450\alpha^2)}$$

By solving the first order condition $\frac{d\pi^t_{ww}}{dm^t_{1ww}}=0$, the profit margin is obtained as follows:

$m^t_{1ww}=\frac{4b(209297a-95720bhr)\lambda^2-(111825a-36808bhr)\alpha^2\lambda+1800h\alpha^4}{433b\lambda(3844b\lambda-497\alpha^2)}$ The profit function is concave because $\frac{d^2\pi^t_{ww}}{d{m^t_{1ww}}^2}=-\frac{866b^2\lambda(3844b\lambda-497\alpha^2)}{(1796b\lambda-225\alpha^2)^2}<0$. Collectively, one can obtain all the decision variables in Scenario WT, given in Proposition-2.

$\Psi_1=238328b^2(3542327a^2-1776808abh+13313536b^2h^2)\lambda^4-248b(98335426a^2+222928115abh+3197168264b^2h^2)\alpha^2\lambda^3+5966495726abh+51629184656b^2h^2\alpha^4\lambda^2-16h(3498383a+5607591bh)\alpha^6\lambda+(1738696351a^2+450496h^2)\alpha^8$, $\Psi_2=3844b^2(109133473a^2-50085968abh+51338880b^2h^2)\lambda^4-b(59626108353a^2-13514464784abh+48162047168b^2h^2)\alpha^2\lambda^3+16(55577025a^2+97535617abh+211429193b^2h^2)\alpha^4\lambda^2-31808h(900a+1813bh)\alpha^6\lambda+230400h^2\alpha^8$

Appendix C. Relations between prices and SI in Scenarios MT and WT

$p^t_{1mm}-p^t_{2mm}=\frac{8(40285a\lambda-239808bh\lambda+17143h\alpha^2)}{\Delta_1}>0$

$p^t_{1wm}-p^t_{2wm}=\frac{4(126759a\lambda-724160bh\lambda+51685h\alpha^2)}{\Delta_1}>0$

$p^t_{1rm}-p^t_{2rm}=\frac{2(126759a\lambda-724160bh\lambda+51685h\alpha^2)}{\Delta_1}>0$

$$p^t_{1mw} - p^t_{2mw} = \frac{2(46189a-244544bh)b\lambda^2+4(7455a+13163bh)\alpha^2\lambda-480h\alpha^4}{433b\Delta_3} > 0$$
$$p^t_{1ww} - p^t_{2ww} = \frac{62b(4089a-23360bh)\lambda^2-497(45a-364bh)\alpha^2\lambda+360h\alpha^4}{433b\Delta_3} > 0$$
$$p^t_{1rw} - p^t_{2rw} = \frac{62b(4089a-23360bh)\lambda^2-497(45a-364bh)\alpha^2\lambda+360h\alpha^4}{866b\Delta_3} > 0$$
$$I^t_m - I^t_w = -\frac{1984b(96939353a-37986208bh)\lambda^2-(5769883231a-2488901208bh)\alpha^2\lambda+92875384h\alpha^4}{1732\lambda\Delta_1\Delta_2}.$$
$$p^t_{1rm} - p^t_{1rw} = \frac{496b(664406995a+434021928bh)\alpha^2\lambda^2-(97351434089a+21214480024bh)\alpha^4\lambda+1567025096h\alpha^6}{1732b\lambda\Delta_1\Delta_2}$$
$$p^t_{2rm} - p^t_{2rw} = \frac{2\alpha^2(2625004257235000\lambda^2-13985408183125\alpha^2\lambda+654326841\alpha^4)}{433b\lambda\Delta_1\Delta_2}$$
$$Q^t_w - Q^t_m = \frac{\alpha^2(3479a\lambda(20944499b\lambda+494018\alpha^2)-8h(5491038897b^2\lambda^2-260051743b\alpha^2\lambda+3458126\alpha^4))}{433\lambda\Delta_1\Delta_2} > 0$$
$$Q^t_m - Q^s_w = \frac{24ab\lambda(71672b\lambda-23051\alpha^2)-62bh(4528b\lambda-63\alpha^2)\Delta_4}{\Delta_1\Delta_4} > 0$$

Appendix D. Proof of Theorem 1

$$\theta^t_m - \theta^t_w = \frac{492032b(497a+729bhr)\alpha\lambda^2-(122763473a+30460120bhr)\alpha^3\lambda+1976072hr\alpha^5}{2\Delta_1\lambda\Delta_2} \geq 0 \text{ if}$$
$$h < \frac{497a\lambda(247009\alpha^2-492032b\lambda)}{8(247009\alpha^4-3807515b\alpha^2\lambda+44836416b^2\lambda^2)} = h_1(say)$$

Now the differences of the profit functions are as follows:

$$\pi^t_{mm} - \pi^t_{mw} = \frac{1}{\Delta_1\lambda\Delta_2{}^2}[12796306976b^3(104776321a^2-43095632abh+48535168b^2h^2)\lambda^5-3844b^2(105541246448421a^2-56135882633744abh+ 537456854396 16b^2h^2)\alpha^2\lambda^4+b(28069045277666659a^2-21789249717939632abh+20236562604331456b^2h^2)\alpha^4\lambda^3+7952(27621781425a^2+60459256049abh- 49874346697b^2h^2)\alpha^6\lambda^2-64h(110487125700a+234554230949bh)\alpha^8\lambda+56910873600h^2\alpha^{10}] \geq 0$$

$$\pi^t_{wm} - \pi^t_{ww} = -\frac{1}{\Delta_1{}^2\lambda\Delta_2}[12796306976b^2(104776321a^2-43095632abh+48535168b^2h^2)\lambda^4-3328904b(67787556081a^2-1065926864abh+ 44111840960b^2h^2)\alpha^2\lambda^3+(15070870303021729a^2+6824898141970608abh+12448611831279840b^2h^2)\alpha^4\lambda^2-3976h(122026892162a+100972533377bh)\alpha^6\lambda+ 3904860549184h^2\alpha^8] \leq 0$$

$$\pi^t_{rm} - \pi^t_{rw} = -\frac{1}{433\Delta_1{}^2\lambda\Delta_2}[63981534888b^2(318007451a^2-131282152abh-212971520b^2h^2)\lambda^4-1664452b(189477152235a^2-23927842276abh- 245534727200b^2h^2)\alpha^2\lambda^3+(15070870303021729a^2-6957070892130996abh+37302655002184896b^2h^2)-3976h(122026892162a-259544447847bh)\alpha^6\lambda+ 3904860549184h^2\alpha^8] \leq 0$$

Hence the theorem.

Appendix E. Proof of Theorem 3

Under MS game, the following inequalities ensure the proof:

$$\theta^t_m - \theta^s_m = \frac{40b\alpha(15581(a-2bh)\lambda+9642bh\lambda+1345h\alpha^2)}{\Delta_1\Delta_3} \geq 0.$$
$$\pi^t_{mm} - \pi^s_{mm} = \frac{16b(77905a^2\lambda^2-13450ah\lambda\Delta_3+h^2(14416b\lambda-961\alpha^2)\Delta_3)}{\Delta_1\Delta_3} \geq 0$$
$$\pi^t_{wm} - \pi^s_{wm} = \frac{8b}{\Delta_1{}^2\Delta_3{}^2}[a^2\lambda^2(4685376811136b^2\lambda^2-66995569152b\alpha^2\lambda-17149624609\alpha^4)-15376ah\lambda(3130373b\lambda-11808\alpha^2)\lambda\Delta_2{}^2+4805h^2(10267776b^2\lambda^2-$$

$1361872b\alpha^2\lambda + 50221\alpha^4)\Delta_3{}^2] \geq 0$

$\pi^t_{rm} - \pi^s_{rm} = \frac{4b}{\Delta_1{}^2\Delta_3{}^2}[5a^2\lambda^2(970467802752b^2\lambda^2 - 17573168896b\alpha^2\lambda - 3299485701\alpha^4) - 29791ah\lambda(1776808b\lambda - 17343\alpha^2)\Delta_3{}^2 + 2h^2(198311775488b^2\lambda^2 -$

$29002245796b\alpha^2\lambda + 1073914633\alpha^4)\Delta_3{}^2] \geq 0$

Under WS game, the following inequalities ensure the proof:

$$\theta^s_w - \theta^t_w = \frac{a\lambda(15376b\lambda^2 - 1988\alpha(2b+\alpha)\lambda + 497\alpha^3) + 8h\alpha(29b\lambda - \alpha^2)(8b\lambda - \alpha^2)}{2\lambda\Delta_2\Delta_4} \geq 0$$

$\pi^t_{mw} - \pi^s_{mw} = \frac{1}{187489b\lambda\Delta_2{}^2\Delta_4}[2a^2\lambda^2(146418025348b^3\lambda^3 - 450336168833b^2\alpha^2\lambda^2 + 5107124288b\alpha^4\lambda - 222308100\alpha^6) - 8ah\lambda\Delta_5(12033153812b^3\lambda^3 -$

$844654049b^2\alpha^2\lambda^2 - 97535617b\alpha^4\lambda + 1789200\alpha^6) + 8h^2\Delta_5(12334165920b^4\lambda^4 - 3010127948b^3\alpha^2\lambda^3 + 211429193b^2\alpha^4\lambda^2 - 3604244b\alpha^6\lambda +$

$14400\alpha^8)] \geq 0$

$$\pi^t_{ww} - \pi^s_{dd} = \frac{4[a^2\lambda^2(77905b\lambda - 7952\alpha^2) + 4h(a\lambda(6725b\lambda + 497\alpha^2) + h(7208b^2\lambda^2 - 729b\alpha^2\lambda + 4\alpha^4))\Delta_5]}{433\lambda\Delta_2\Delta_4} \geq 0$$

$\pi^t_{rw} - \pi^s_{rw} = \frac{1}{1499912b\lambda\Delta_2{}^2\Delta_4{}^2}[a^2\lambda^2(9704678027520b^4\lambda^4 - 3606415714304b^3\alpha^2\lambda^3 + 604723719672b^2\alpha^4\lambda^2 - 52206327264b\alpha^6\lambda + 1738696351\alpha^8) +$

$2ah\lambda\Delta_5{}^2(211731548512b^3\lambda^3 + 27643086260b^2\alpha^2\lambda^2 - 2983247863b\alpha^4\lambda + 27987064\alpha^6) - 16h^2\Delta_5{}^2(198311775488b^4\lambda^4 - 49556108092b^3\alpha^2\lambda^3 +$

$3226824041b^2\alpha^4\lambda^2 - 5607591b\alpha^6\lambda + 28156\alpha^8)] \geq 0.$

Appendix F. Proof of Theorem 5

$$RGP^s_{1w} - RGP^s_{1m} = RGP^s_{2w} - RGP^s_{2m} = \frac{\alpha^3}{14\lambda(14b\lambda - \alpha^2)} > 0$$
$$RGP^t_{1m} - RGP^s_{1m} = \frac{(131521a - 42352bh)\lambda\alpha + 1017h\alpha^3}{7\lambda((1466021a - 310328bh)\lambda + 2034\Delta_4)} > 0$$
$$RGP^t_{1w} - RGP^s_{1m} = \frac{8b(20193a - 205648bh)\alpha\lambda^2 + (438851a + 109976bh)\alpha^3\lambda - 7064h\alpha^5}{14\lambda(124b(47291a - 9416bh)\lambda^2 - (438851a + 12984bh)\alpha^2\lambda + 7064h\alpha^4)} > 0$$
$$RGP^t_{2m} - RGP^s_{2m} = \frac{(389801a - 808864bh)\lambda\alpha + 53719h\alpha^3}{14\lambda(62(21601a + 6972bh)\lambda - 53719h\alpha^2)} > 0$$
$$RGP^t_{2m} - RGP^s_{2m} = \frac{(394121a + 471792bh)\alpha^3\lambda + 4b(167145a - 1135456bh)\alpha\lambda^2 - 6344h\alpha^5)}{14\lambda(248b(21601a + 6972bh)\lambda^2 - (394121a + 374800bh)\alpha^2\lambda + 6344h\alpha^4)} > 0$$

Therefore, the theorem is proved.

Appendix G. Optimal decision in Scenario PTP

To find the optimal decision in Scenario PTP, we used transformation $m^t_{iwp} = p^t_{iwp} - p^t_{imp}, (i = 1, 2)$ and $m^t_{irp} = p^t_{irp} - p^t_{iwp}, (i = 1, 2)$. By solving $\frac{d\pi^t_{2rp}}{dm^t_{2rp}} = 0$, the profit margin of the retailer is obtained as, $m^t_{2rp}(p^t_{2mp}, \theta^*_p) = \frac{a - b(m^t_{2mp} + m^t_{2wp}) + \alpha\theta^*_p}{2b}$. The profit function of the retailer is concave because $\frac{d^2\pi^t_{2rp}}{dm^t_{2rp}{}^2} = -2b < 0$. Using the value of m^t_{2rp} and solving $\frac{d\pi^t_{2mp}}{dp^t_{2mp}} = 0$, the wholesale-price for the manufacturer in second period is obtained as $p^t_{2mp}(m^t_{2wp}, \theta^*_p) = \frac{a - 2I^t_p - bm^t_{2wp} + \alpha\theta^*_p}{2b}$. The profit function is concave because $\frac{d^2\pi^t_{2mp}}{dp^t_{2mp}{}^2} = -b < 0$. Now substituting the response of the retailer and manufacturer, the wholesaler's profit margin for the second period is obtained by solving $\frac{d\pi_{2wp}^t}{dm_{2wp}^t} = 0$. On simplification, $m_{2wp}^t(I_p^t, \theta_p^*) = \frac{a - 2I_p^t + \alpha\theta_p^*}{2b}$. The profit function is also concave because $\frac{d^2\pi_{2wp}^t}{dm_{2wp}^t{}^2} = -\frac{b}{2} < 0$. Substituting the optimal responses obtained in the second period, the profit function for the retailer is obtained as follows:

$$\pi_{rw}^t = \frac{1}{64b}[(1-\phi)((a+\alpha\theta_p^*)^2 + 60I_p^t(a - I_p^t + \alpha\theta_p^*)$$

$$-64b(bm_{1rp}^t + I_p^t)(m_{1wp}^t + p_{1mp}^t) + 64(a + \alpha\theta_p^* - bm_{1rp}^t)bm_{1rp}^t - 64bhI_p^t]$$

By solving $\frac{\partial\pi_{rp}^t}{\partial m_{1rp}^t} = 0$ and $\frac{\partial\pi_{rp}^t}{\partial I_p^t} = 0$, one can obtain the profit margin and amount of SI as: $m_{1rp}^t(p_{1mp}^t, \theta_p^*) = \frac{a - b(p_{1mp}^t + m_{wp}^t) + \alpha\theta_p^*}{2b}$ and $I_p^t(p_{1mp}^t, \theta_p^*) = \frac{15a - 16b(h + m_{1wp}^t + p_{1mp}^t) + 15\alpha\theta_p^*}{30}$

Because $\frac{\partial^2\pi_{rp}^t}{\partial m_{1rp}^t{}^2} = -2b(1-\phi) < 0$ and $\frac{\partial^2\pi_{rp}^t}{\partial m_{1rp}^t{}^2} \times \frac{\partial^2\pi_{rp}^t}{\partial I_p^t{}^2} - \left(\frac{\partial^2\pi_{rp}^t}{\partial m_{1rp}^t \partial I_p^t}\right)^2 = \frac{15(1-\phi)^2}{4} > 0$, the profit function for the retailer is concave. Using these obtained response, profit function for the manufacturers is obtained as follows:

$$\pi_{mp}^t = \frac{b}{900}[16h^2(2+4\psi+15\phi)+32h(2m_{1wp}^t - 13p_{1mp}^t - 11m_{1wp}^t\psi + 4p_{1mp}^t\psi + 15(m_{1wp}^t + p_{1mp}^t)\phi)$$

$$+(m_{1wp}^t + p_{1mp}^t)(m_{1wp}^t(32 - 866\psi + 465\psi) - p_{1mp}^t(898 - 64\psi - 465\phi))]$$

$$+\frac{(2(p_{1mp}^t + m_{1wp}^t\psi) - (h + 2(m_{1wp}^t + p_{1mp}^t))\phi)(a + \alpha\theta_p^*)}{2} + \frac{\phi(a+\alpha\theta_p^*)^2}{2b} - 2\theta_p^{*2}\lambda$$

Solving $\frac{d\pi_{mp}^t}{dp_{1mp}^t} = 0$, one can find the wholesale-price of the manufacturer for the first period as:

$p_{1mp}^t(m_{1wp}^t) = \frac{bm_{1wp}^t(433+401\psi-465\phi) - 450a(1-\phi) + 16bhr(13-4\psi-15\phi) - 450(1-\phi)\alpha\theta_p^*}{b(-898+64\psi+465\phi)}$. The concavity condition holds because $\frac{\partial^2\pi_{mp}^t}{\partial p_{1mp}^t{}^2} = -\frac{b(898-64\psi-465\phi)}{450} < 0$

Finally, the wholesaler profit function is obtained as follows:

$$\pi_{wp}^t = \frac{1}{2b(898-64\psi-465\phi)^2}[(1-\psi)(28800(a+\alpha\theta_p^*)^2(1-\phi)^2 + 2(a+\alpha\theta_p^*)b(960h(1-\phi)(46-15\phi)+$$

$$m_{1wp}^t(418594 - 231105\phi - 128\psi(898 - 32\psi - 465\phi))) + b^2(32h^2(46-15\phi)^2$$

$$-961m_{1wp}^t{}^2(1-\psi)(866-32\psi-465\phi) - 16hm_{1wp}^t(8\psi(898-32\psi-465\phi)+5(4786-2697\phi)))]$$

By solving the first order condition $\frac{d\pi_{wp}^t}{dm_{1wp}^t} = 0$, the profit margin is obtained as follows: $m_{1wp}^t = \frac{(a+\alpha\theta_p^*)(418594-231105\phi-128\psi(898-32\psi-465\phi)) - 8bh(8\psi(898-32\psi-465\phi)+5(4786-2697\phi))}{961b(1-\psi)(866-32\psi-465\phi)}$ The profit function is concave because $\frac{d^2\pi_{wp}^t}{d{m_{1wp}^t}^2} = -\frac{961b(1-\psi)^2(866-32\psi-465\phi)}{(898-64\psi-465\phi)^2} < 0$. Collectively, one can obtain all the decision variables in Scenario PTP, as shown in Proposition-5.

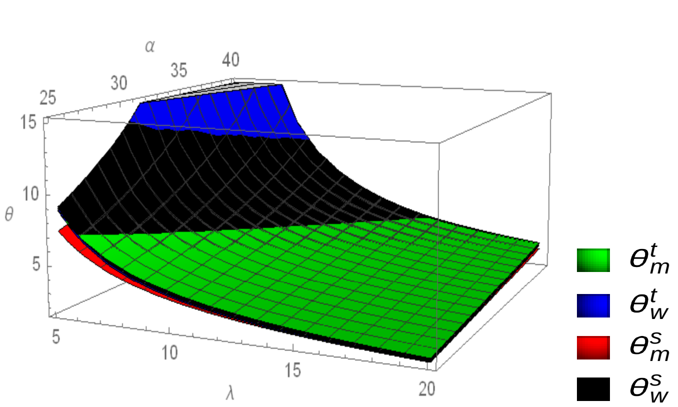

Fig 1a. GLs in Scenarios MT, MS, WT, WS.

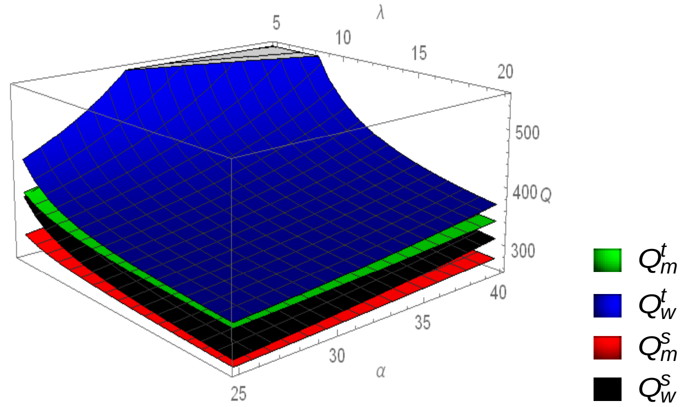

Fig 1b. Sales volumesin Scenarios MT, MS, WT, WS.

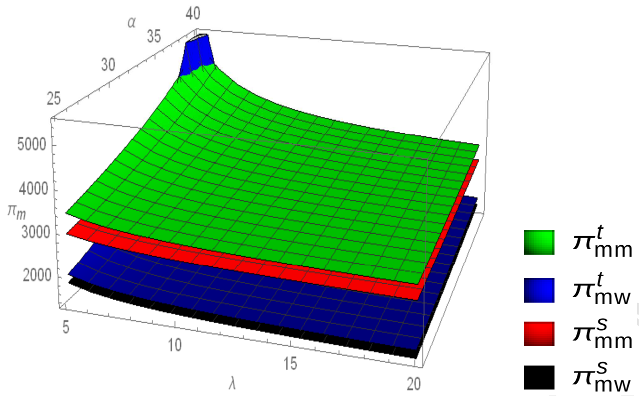

Fig 1c. Profits of the manufacturer in Scenarios MT, MS, WT, WS.

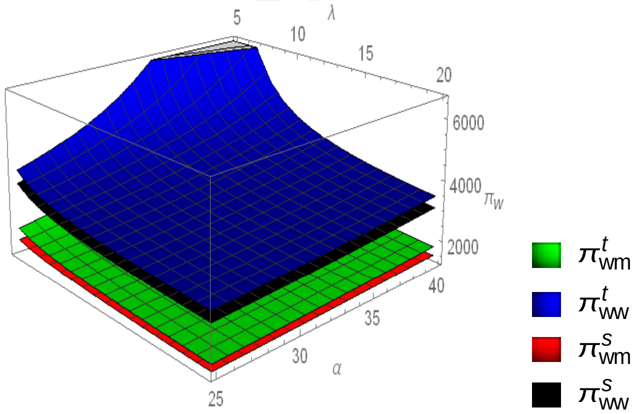

Fig 1d. Profits of the wholesaler in Scenarios MT, MS, WT, WS

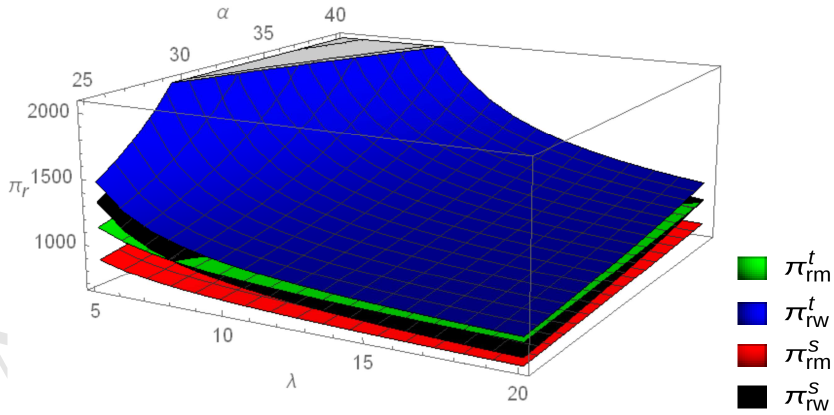

Fig 1e.Profits of the retailer in Scenarios MT, MS, WT, WS

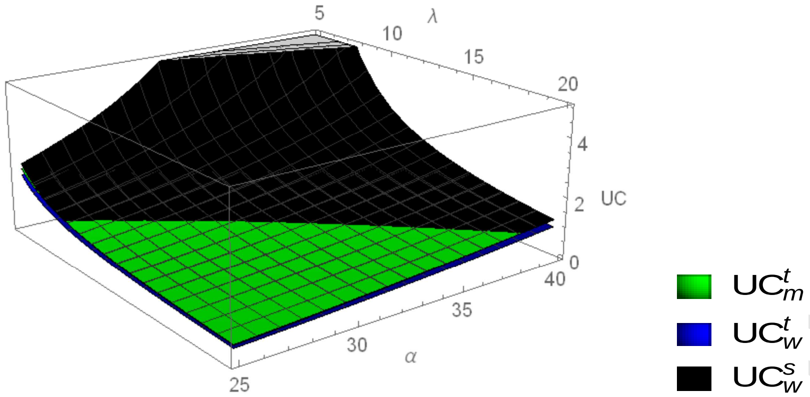

Fig- 2. UCs of the manufacturer in Scenarios MT, WT, WS.

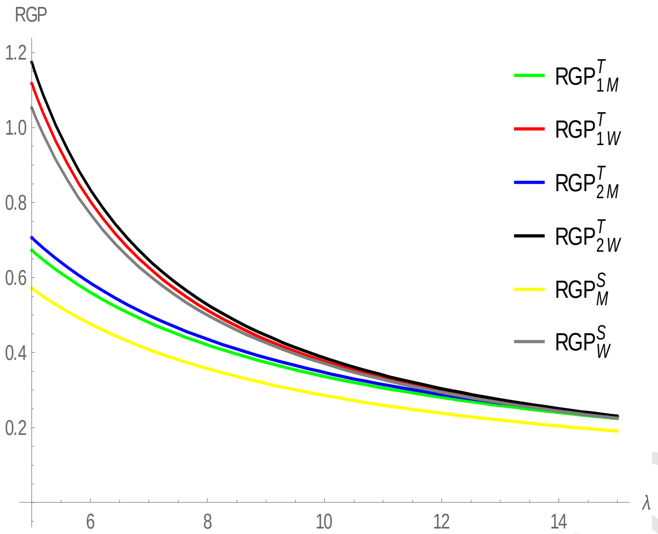

Fig 3a. Variation of RGP in different scenarios with respect to **λ**

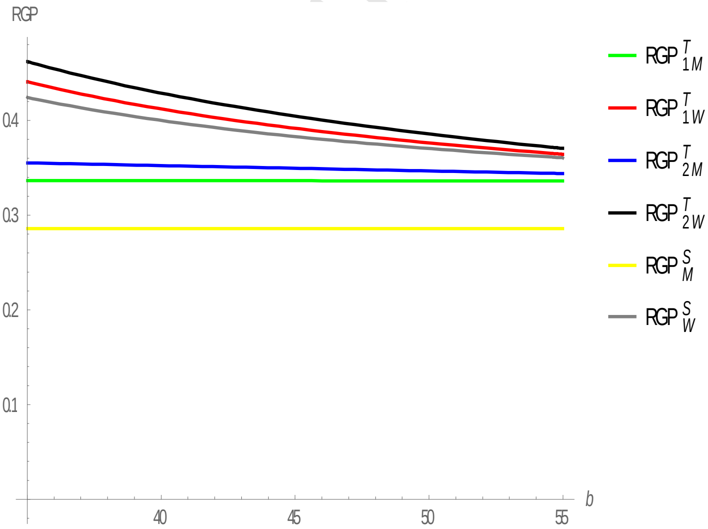

Fig 3b. Variation of RGP in different scenarios with respect to **b**

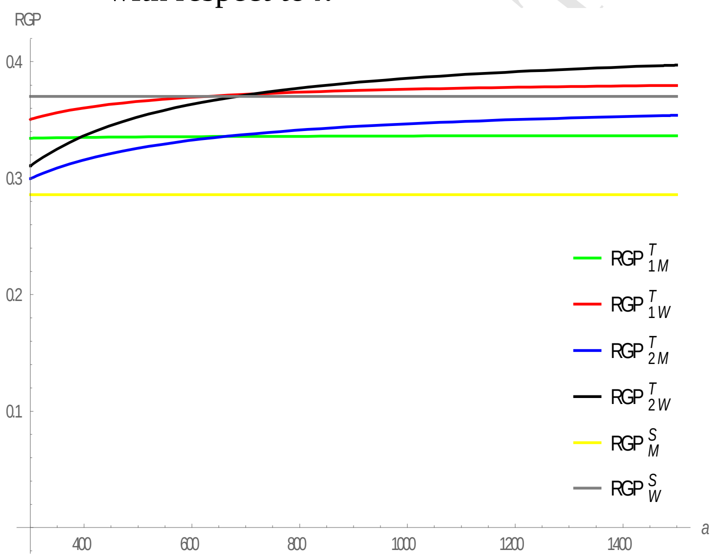

Fig 3c. Variation of RGP in different scenarios with respect to a

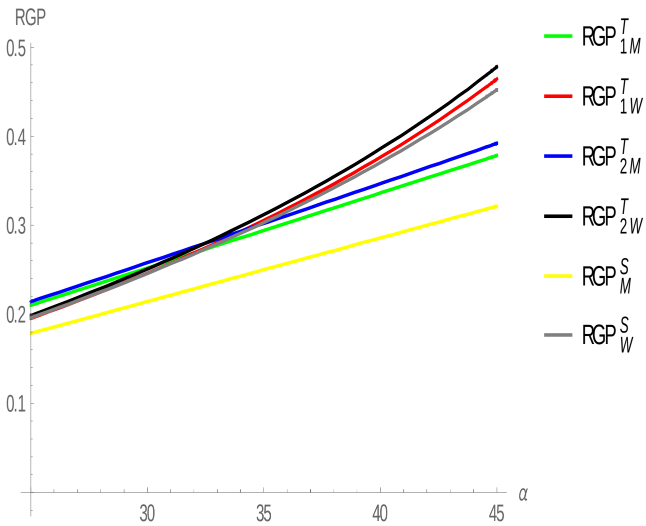

Fig 3d. Variation of RGP in different scenarios with respect to α

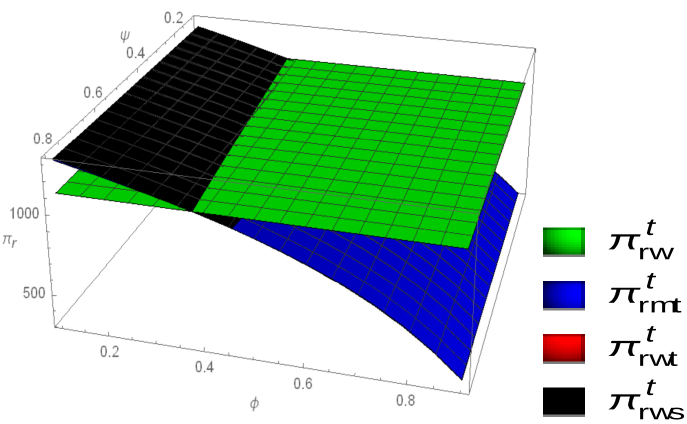

Fig 4a. Profits of the retailer under different scenarios

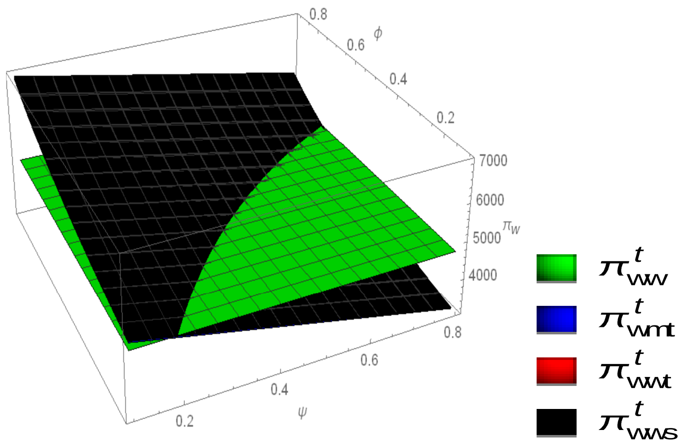

Fig 4b. Profits of the wholesaler under different scenarios

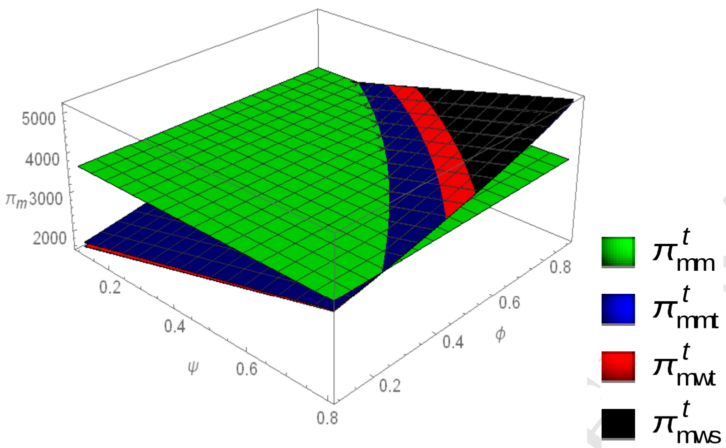

Fig 4c. Profits of the manufacturer under different scenarios

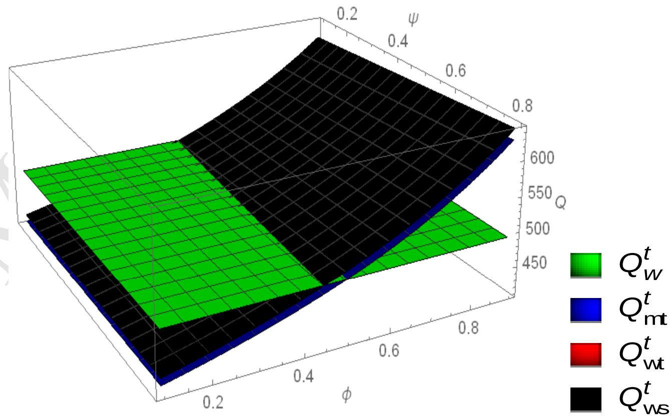

Fig 4d. Sales volume under different scenarios