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Impacts of Power Structure on Sustainable Supply Chain Management

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Abstract: The present paper examines the manufacturer's operational decisions, e.g., wholesale price and product sustainability level, the retailer's operational decision, e.g., retail margin, and supply chain efficiency under three supply chain power structures: manufacturer Stackelberg, Nash and retailer Stackelberg. As a benchmark, we first obtain the equlibrium price and product sustainability level in a vertically integrated supply chain. Our analysis provides some interesting findings in a decentralized supply chain: (i) a dominant manufacturer (retailer) always benefits from its power; (ii) the entire supply chain earns the most profit from the Nash game, and the least from the retailer Stackelberg game, respectively; (iii) as the power shifts from the manufacturer to the retailer, product sustainability and retail price increase; (iv) dominant manufacturer does not necessarily imply low wholesale price that would benefit the retailer. Managerial insights are provided for the manufacturer and the retailer, respectively.

Keywords: sustainability; power structures; supply chain management

1. Introduction

During the past few decades, a large and increasing number of manufacturers are gradually realizing the potential economical, social and environmental benefits from the research and development of sustainable products [1]. The concept of sustainable product involves manufacturing products through economically-sound processes that minimize detrimental environmental impacts while saving energy and protecting natural resources (https://archive.epa.gov/sustainablemanufacturing/web/html/). In other words, Sustainable products are those that provide environmental, societal, and economic benefits while protecting public health, welfare, and the environment over their full commercial cycle [2]. More specifically, the key elements associated with product sustainability comprise environmental impact, resource utilization and economy, manufacturability, functionality, societal impact, and recyclability/remanufacturability [3]. As a consequence, the significance of product sustainability has been increasingly recognized by both industry practitioners and academic researchers. Operations management, sales & marketing are increasingly connected to sustainability, which is currently taken into account as the operational drivers of profitability and competitive edge [4]. To this end, a growing number of companies, such as Hennes & Mauritz, Marks & Spencer, Levis, and Coca Cola, are publishing sustainability goals as an effective way of expanding market share, and competing with rivals for superior positioning. Meanwhile, consumers reasonably have strong willingness to buy the products with higher sustainability levels [5–7]. As the foremost alliance for sustainable production of apparel, footwear and home textile, the Sustainable Apparel Coalition (SAC) (http://apparelcoalition.org/the-coalition/) has constructed the Higg index (http://apparelcoalition.org/the-higg-index/) to measure sustainability performance for addressing inefficiencies, resolving damaging practice and achieving environmental and social transparency that consumers are starting to demand.

The interaction between product sustainability and supply chains is the critical strategy from recent investigations of operations & sustainability [8] and operations & environment [9]. By doing so, the emphasis on product sustainability management and operations is moved from the local optimization of sustainability factors to the overall supply chain [10]. This is an important and timely topic that captures increasing concerns on sustainability, therefore affects operations under the framework of supply chain management. Given the fact that a product is distributed from the manufacturer to the retailer, and to the consumers, a critical strategy on supply chain management is the wider adoption and development of sustainability practices [11].

The concept of power is critical in elaborating the interactions among different supply chain members [12]. El-Ansary and Stern [13] defines "the power of a supply chain member is its ability to control the decision variables of another member at a different level in the supply chain". In this study we develop a game-theory framework to model power in a two-echelon supply chain consisting of an upstream manufacturer and a downstream retailer. Power within the supply chain is represented by the events sequence in a non-cooperative game. We employ a manufacturer (retailer) Stackelberg game to model supply chains with a dominant manufacturer (retailer). Considering supply chains with no dominant players, we employ a Nash game in which both parties move simultaneously. The decision variables of the manufacturer are wholesale price and product sustainability level, while the retailer makes decision on retail margin.

The purpose of this paper is to investigate the effects of power structure on managerial decision-making including wholesale price, sustainability and retail margin, and then answers the following research questions:

- How does power structure affect the manufacturer's decisions about wholesale price and product sustainability?
- How does power structure affect the retailer's decision about retail margin?
- How does power structure affect supply chain efficiency, in terms of the profits of the manufacturer, the retailer and the entire supply chain?

Our analysis in this work provides the following results. First, a dominant manufacturer (retailer) always benefits from its power. Second, the entire supply chain earns the most profit from the Nash game, and the least from the retailer Stackelberg game, respectively. Third, as the power shifts from the manufacturer to the retailer, product sustainability and retail price increase. Fourth, dominant retailer unconventionally accepts the highest wholesale price to benefit herself.

The rest of this paper is organized as below. Section 2 reviews related work in the literature. Section 3 describes the key elements of the model and the benchmark. Section 4 analyzes the decentralized supply chain. Section 5 provides meaningful analysis. Section 6 concludes this study.

2. Related Work

Our paper relates to the literature on decision-making under different power structures in the supply chain management. Choi [14] investigates three noncooperative games between two manufacturers and a common retailer, under three different power structures: manufacturer Stackelberg, Nash, and retailer Stackelberg, and demonstrates that some of the results depend heavily on the form of demand function: linear or nonlinear. Following the supply chain framework proposed by [14], Pan et al. [15] compare revenue-sharing and wholesale price mechanisms under different channel power structures, and identify the certain conditions wherein the players favor the revenue-sharing contract. Benton and Maloni [16] empirically test the influences of supply chain power on supplier satisfaction, and show how the buyer–seller relationship affects supplier satisfaction. Nagarajan and Sošic [17] analyze a decentralized assembly system consisting of with multiple supplier coalitions selling complementary components to a downstream assembler, under three game modes, and predict the structure of possible supplier alliances as a function of the power strucutre in the market, the number of suppliers, and the structure of demand. Ma et al. [18] optimize the manufacturer's and the retailer's effort levels and profits under three different power structures, in the presence of quality and marketing effort-dependent demand. Sensitivity analysis with respect to the marketing and cost coefficients under different power structures are provided. Shi et al. [12] examine the impacts of power structures and demand uncertainty on supply chain members, and show that whether a player benefits from its power depends on the expected demand model but not on demand shock model. Xue et al. [19] unlock the effect of different power schemes on the supply chain partners' performance and consumer surplus, based upon a game-theory based framework. Bian et al. [20] study the impact of service outsourcing under three supply chain power structures, and find that a lower retail price or a higher service level could occur in the decentralized channel with service outsourcing compared to those in the integrated channel, but they never occur simultaneously. Chen et al. [21] study the impact of the supply chain power structure on pricing decisions and the performance, within a retail service supply chain with an online-to-offline (O2O) mixed dual-channel. Chen et al. [22] examine the role of power relationship and coordination in a two-echelon sustainable supply chain management that consists of a manufacturer and a retailer whose customer demand is carbon emission sensitive. A two-part tariff contract is designed to coordinate the supply chain.

There are a number of papers addressing sustainable supply chain management. Dong et al. [23] examine the sustainability investment on sustainable product with emission regulation consideration for centralized and decentralized supply chains, and conclude that the sustainability investment efficiency has a significant impact on the optimal order quantity solutions. Li and Li [7] develop the game model between two sustainable supply chains competing in product sustainability, obtain equilibrium results and provide meaningful managerial insights. They find that although vertical integration is a Nash equilibrium, it will be Pareto optimal only when the competition degree is low. Formentini and Taticchi [24] propose an empirical investigation to analyze seven case studies through the lenses of contingency theory, the strategic alignment perspective and the resource-based view of organisations. Wu et al. [25] apply interval-valued triangular fuzzy numbers associated with grey relational analysis to improve the insufficient information and overcome the incomplete system under uncertainty. Xie [11] improves sustainability through a mathematical modelling and a cooperative game in a decentralized supply chain with two suppliers. The mechanism used in the selection of cooperative strategies is described, and the decisions related to demand, energy efficiency and profits are analyzed in different scenarios of cooperative strategy combinations. Svensson [26], Seuring and Müller [27], Brandenburg et al. [28], Ansari and Kant [29] provide systematic literature reviews on this piece of research. Carter and Easton [30], Walker et al. [31], Dubey et al. [32] summarize the research trends and propose the future research directions of sustainable supply chain management.

Our paper differs from these papers in examining the impacts of different power structures on the operational decisions including wholesale price, sustainability level and retail margin, and the performance of supply chain members. To the best of knowledge, this study is completely new and will provide meaningful insights into sustainable supply chain management. More specifically, based upon the traditional Mussa-Rosen utility function [33], this work provides precise analysis on the aforementioned decisions.

3. Model and Benchmark Results

In this section, we outline the basic model and investigate the vertically integrated supply chain as the benchmark.

3.1. Basic Model

Consider a market, with size normalized to 1, that consists of consumers whose willingness to pay for the sustainability are heterogeneous. More specifically, a consumer of type θ is willing to pay for at most θs for a product with sustainability s. The consumer heterogeneity is assumed to be uniformly distributed in the interval [0,1]. This assumption gives rise to a linear demand function, which allows us to ignore the imperfect competition sustainability distortions [34]. We also assume that consumers can accurately perceive the product sustainability. This assumption is in line with that of [35]. The product is distributed through a two-echelon supply chain composed of an upstream manufacturer (he) and a downstream retailer (she), both of them are risk-neutral. The retailer buys a product from the manufacturer at a wholesale price w determined by the manufacturer, and then decides the retail margin m to sell the product at the price $p = w + m$ in the market. In addition, the unit cost for making a product with sustainability level s is λs^2, where the parameter λ captures the manufacturer's cost of sustainability. This quadratic function implies that the manufacturer can choose any sustainability level, and has been extensively used in the literature [23]. Each consumer purchases at most one unit of the product. Therefore, the net utility of a consumer of type θ obtained from buying a product with sustainability s at price p is $U(p, q; \theta) = \theta s - p$ [35]. The net-utility-maximizing consumer of type θ buys a product if and only if $\theta s - p \geq 0$. Therefore, all consumers of $\theta \geq \frac{p}{s}$ will purchase the product. Thus the sales quantity in the market is $q = 1 - \frac{p}{s}$.

3.2. Benchmark: The Integrated Channel

In this subsection, we examine a benchmark case where the manufacturer and the retailer are owned and managed by a single, integrated manager who jointly determines the product sustainability and price to maximize the total profit of the supply chain. The integrated manager's optimization problem is

$$\max_{p,s} \left(p - \lambda s^2\right)\left(1 - \frac{p}{s}\right). \tag{1}$$

The equilibrium solutions in this scenario are denoted by superscript I. Proposition 1 quantifies the manager's optimal product sustainability, price, sale quantity and profit, which are used as a benchmark for the forthcoming comparisons with the decentralized supply chain.

Proposition 1. *In an integrated supply chain, the optimal product sustainability is* $s^I = \frac{1}{3\lambda}$*, price is* $p^I = \frac{2}{9\lambda}$*, sales quantity is* $q^I = \frac{1}{3}$ *and profit is* $\Pi^I = \frac{1}{27\lambda}$.

4. The Decentralized Supply Chain

In this section, we study a two-echelon decentralized supply chain consisting of an upstream manufacturer and a downstream retailer under the following three different power structures [12,20]:

- Manufacturer Stackelberg denoted by superscript "*MS*": the manufacturer acts first as the Stackelberg leader determining the wholesale price and the product sustainability level, while the retailer moves as the follower to set the profit margin taken the manufacturer's decisions as given;
- Nash denoted by superscript "*N*": the manufacturer and the retailer with a balanced power structure move simultaneously to determine the wholesale price, the product sustainability level and the profit margin;
- Retailer Stackelberg denoted by superscript "*RS*": the retailer acts first as the Stackelberg leader to set the profit margin, while the manufacturer moves as the follower to determine the wholesale price and the product sustainability level, taken the retailer's decision as given.

Different power structures are represented by different decision sequences in which the wholesale price, the product sustainability level and retail margin are set by the manufacturer and the retailer, respectively.

Hereafter, we use superscripts including "*MS*", "*N*" and "*RS*" to indicate the typical non-cooperative game model and subscript including "*M*" and "*R*" to index the supply chain members throughout this paper. For instance, $\Pi_M^{MS}(\cdot)$ is the manufacturer's profit in the manufacturer Stackelberg game.

In a decentralized supply chain, the corresponding profit functions of the manufacturer and the retailer are:

$$\Pi_M = \left(w - \lambda s^2\right)\left(1 - \frac{w+m}{s}\right), \tag{2}$$

$$\Pi_R = m\left(1 - \frac{w+m}{s}\right). \tag{3}$$

The objectives of the manufacturer and the retailer are to individually maximize their own profits, i.e., Π_M and Π_R.

4.1. Manufacturer Stackelberg Model

In the scenario of Manufacturer Stackelberg, the upstream manufacturer considers the downstream retailer's reaction when deciding his operational decisions including the wholesale price and the product sustainability level. The retailer's decision on retail margin for a given (s, w) can be obtained from the first-order derivative of Π_R in (3):

$$\frac{\partial \Pi_R}{\partial m} = 1 - \frac{w+2m}{s} = 0, \tag{4}$$

that is $m = \dfrac{s-w}{2}$. After substituting m into (2), we obtain

$$\Pi_M = \frac{(w-q)\left(\lambda s^2 - w\right)}{2s}. \tag{5}$$

We solve the first-order derivatives of Π_M with respect to w and s, and obtain

$$\frac{\partial \Pi_M}{\partial w} = \frac{s + \lambda s^2 - 2w}{2s} = 0, \tag{6}$$

$$\frac{\partial \Pi_M}{\partial s} = \frac{w^2 + \lambda s^2 (w - 2s)}{2s^2} = 0. \tag{7}$$

After simultaneously solving (6) and (7), we find the manufacturer's optimal wholesale price and product sustainability in *MS* are

$$w^{MS} = \frac{2}{9\lambda}, \quad s^{MS} = \frac{1}{3\lambda}, \tag{8}$$

and then $m^{MS} = \dfrac{1}{18\lambda}$.

Consequently, we derive the profits of manufacturer, retailer and total supply chain based upon the above optimal values,

$$\Pi_M^{MS} = \frac{1}{54\lambda}, \quad \Pi_R^{MS} = \frac{1}{108\lambda}, \quad \Pi^{MS} = \frac{1}{36\lambda}. \tag{9}$$

4.2. Retailer Stackelberg Model

To begin, we introduce a Lemma for solving the retail Stackelberg game model.

Lemma 1. *The retailer's profit function is jointly concave with respect to w and s when* $m^2 + 2\lambda(m+w)s^2 - 4\lambda s^3 + \lambda^2 s^4 < 0$.

As for the case of Retailer Stackelberg, we take the first-order derivatives of Π_M with respect to w and s, and derive

$$\frac{\partial \Pi_M}{\partial w} = \frac{s + \lambda s^2 - m - 2w}{s} = 0, \tag{10}$$

$$\frac{\partial \Pi_M}{\partial s} = \frac{w\left(m+w\right)+\lambda s^2\left(m+w-2s\right)}{s^2} = 0. \tag{11}$$

Solving (10) and (11) together, we obtain

$$w = \frac{1-3m\lambda+\sqrt{1+12m\lambda}}{9\lambda}, \tag{12}$$

$$s = \frac{1+\sqrt{1+12m\lambda}}{6\lambda}. \tag{13}$$

Substituting (12) and (13) into (3) and setting the first-order derivative of Π_R with respect to m to zero, and we obtain

$$m^{RS} = \frac{1+2\sqrt{7}}{54\lambda}. \tag{14}$$

We substitute (14) into (12) and (13) and derive the manufacturer's optimal wholesale price and product sustainability as

$$w^{RS} = \frac{17-2\sqrt{7}+6\sqrt{11+4\sqrt{7}}}{162\lambda}, \quad s^{RS} = \frac{3+\sqrt{11+4\sqrt{7}}}{18\lambda}. \tag{15}$$

Finally, we substitute (14) and (15) into (2) and (3) to derive the profits of manufacturer, retailer and the total supply chain in *RS*

$$\Pi_M^{RS} = \frac{\left(7-4\sqrt{7}+3\sqrt{11+4\sqrt{7}}\right)^2}{1458\left(3+\sqrt{11+4\sqrt{7}}\right)\lambda}, \tag{16}$$

$$\Pi_R^{RS} = \frac{\left(7-4\sqrt{7}+3\sqrt{11+4\sqrt{7}}\right)\left(1+2\sqrt{7}\right)}{486\left(3+\sqrt{11+4\sqrt{7}}\right)\lambda}, \tag{17}$$

$$\Pi^{RS} = \frac{113+10\sqrt{7}+51\sqrt{11+4\sqrt{7}}-6\sqrt{77+28\sqrt{7}}}{1458\left(3+\sqrt{11+4\sqrt{7}}\right)\lambda}. \tag{18}$$

4.3. Nash Model

In the case of Nash model, the manufacturer and the retailer with the same channel power make their operational decisions simultaneously. In other words, we solve (4), (10) and (11) at the same time, and then obtain

$$w^N = \frac{6}{25\lambda}, \quad s^N = \frac{2}{5\lambda}, \quad m^N = \frac{2}{25\lambda}. \tag{19}$$

By incorporating (19) into (2) and (3) we obtain the profits of the manufacturer, retailer and total supply chain as below

$$\Pi_M^N = \frac{2}{125\lambda}, \quad \Pi_R^N = \frac{2}{125\lambda}, \quad \Pi^N = \frac{4}{125\lambda}. \tag{20}$$

5. Analysis

For the purpose of presenting analysis of the operational decisions associated with the wholesale price, the product sustainability, the retail margin under channel power structures, we summarize the equilibrium outcomes in the decentralized supply chain in the following Table 1.

Table 1. Equilibrium outcomes in the decentralized supply chain.

	MS	***RS***	***N***
Wholesale price	$\frac{2}{9\lambda}$	$\frac{17-2\sqrt{7}+6\sqrt{11+4\sqrt{7}}}{162\lambda}$	$\frac{6}{25\lambda}$
Sustainability	$\frac{1}{3\lambda}$	$\frac{3+\sqrt{11+4\sqrt{7}}}{18\lambda}$	$\frac{2}{5\lambda}$
Retail price	$\frac{5}{18\lambda}$	$\frac{10+2\sqrt{7}+3\sqrt{11+4\sqrt{7}}}{81\lambda}$	$\frac{8}{25\lambda}$
Sales quantity	$\frac{1}{6}$	$\frac{7-4\sqrt{7}+3\sqrt{11+4\sqrt{7}}}{27+9\sqrt{11+4\sqrt{7}}}$	$\frac{1}{5}$
Manufacturer's profit	$\frac{1}{54\lambda}$	$\frac{\left(7-4\sqrt{7}+3\sqrt{11+4\sqrt{7}}\right)^2}{1458\left(3+\sqrt{11+4\sqrt{7}}\right)\lambda}$	$\frac{2}{125\lambda}$
Retailer's profit	$\frac{1}{108\lambda}$	$\frac{\left(7-4\sqrt{7}+3\sqrt{11+4\sqrt{7}}\right)\left(1+2\sqrt{7}\right)}{486\left(3+\sqrt{11+4\sqrt{7}}\right)\lambda}$	$\frac{2}{125\lambda}$
Supply chain profit	$\frac{1}{36\lambda}$	$\frac{113+10\sqrt{7}+51\sqrt{11+4\sqrt{7}}-6\sqrt{77+28\sqrt{7}}}{1458\left(3+\sqrt{11+4\sqrt{7}}\right)\lambda}$	$\frac{4}{125\lambda}$

Proposition 2. *The comparison of the product sustainability between the decentralized and the integrated supply chains is* $s^{RS} > s^N = s^I > s^{MS}$*. More specifically,* $s^{MS} = 0.83s^I, s^{RS} = 1.06s^I$.

Proposition 2 indicates that the Nash model in the decentralized supply chain offers the same product sustainability level as that of the vertical integrated channel. Meanwhile, the power transfers from the retailer to the manufacturer, the product sustainability level decreases. Reference [36] claims that when consumer heterogeneity is uniformly distributed in willingness to pay, a manufacturer may provide the same or the lower quality in a decentralized channel than in an integrated channel. Because the sustainability could be reasonably considered as an attribute of product quality, Proposition 2 contradicts this result by concluding that the retailer Stackelberg game model could provide a higher sustainability level than that in an integrated supply chain. Compared with the benchmark with vertical integrated channel, the manufacturer Stackelberg game model lowers the product sustainability level by 16.67%, and the retailer Stackelberg game model increases the product sustainability level by 6.19%. Interestingly, Proposition 2 provides some new insights on the interaction between product sustainability design and power structure.

Proposition 3. *The comparison of the manufacturer's wholesale price under different power structures is* $w^{RS} > w^N > w^{MS}$.

Proposition 3 shows that as the power shifts from the manufacturer to the retailer, the wholesale price increases. Conventional wisdom [12] suggests that as the retailer's power increases in the supply chain, the wholesale price decreases. The inconsistence between these results may generated from the fact that the product sustainability level increases when the power shifts to the retailer. A manufacturer intuitively charges higher wholesale price for the product of higher sustainability.

Proposition 4. *The comparison of the retail margin under different power structures is* $m^{RS} > m^N > m^{MS}$.

Proposition 4 demonstrates that as the power shifts from the manufacturer to the retailer, the retail margin increases. [12,14] state that the retail margin increases as the retail power increases in a supply chain for both deterministic and stochastic linear demand functions, but without considering other demand-enhancing factors, i.e., service, quality, and advertising, etc. Proposition 4 shows that the incorporation of product sustainability does not change these insights. Such a result will not be altered in the case of considering the effect of product quality and warranty determined by the manufacturer.

Proposition 5. *The comparison of the retail price between the decentralized and the integrated supply chains is* $p^{RS} > p^N > p^{MS} > p^I$. *Precisely speaking,* $p^{RS} = 1.62p^I, p^N = 1.44p^I, p^{MS} = 1.25p^I$.

Proposition 5 claims that the retail price in a vertically integrated supply chain is always lower than those in the decentralized supply chains. In addition, the retail price is lowest when the supply chain is managed by a central manager, where neither dominates the supply chain. More specifically, the retail prices charged by the retailer are 62%, 44% and 25% of that in the manufacturer Stackelberg, Nash and retailer Stackelberg game models than this in the vertical integrated supply chain, respectively. Proposition 5 denies the prediction results in some trade papers that a power retailer would charge a low retail price [37], but is in line with the observation proposed by [12]. The superiority of our result over that of [12] is providing exact comparisons about the retail prices between the manufacturer and the retailer Stackelberg game models.

Because that all consumer demand is eventually met in our analysis, consumer welfare can therefore be measured by the retail price. That is, consumer welfare increases with respect to the decreasing of retail price. Proposition 5 shows that the decentralized supply chain significantly hurts consumers when compared with the vertically integrated supply chain. As the power transfers from the manufacturer to the retailer in a decentralized supply chain, consumers are worse off due to the increase of retail price.

Proposition 6. *The comparisons of the manufacturer's and the retailer's profits under different power structures are:* $\Pi_M^{MS} > \Pi_M^N > \Pi_M^{RS}$ *and* $\Pi_R^{RS} > \Pi_R^N > \Pi_R^{MS}$.

Proposition 6 claims that as the manufacturer and the retailer become more powerful in the supply chain, the corresponding profits increase. To explicitly show the impact of power structures on supply chain members' profits, we consider the Nash model as the benchmark. Therefore, $\Pi_M^{MS} = 1.16\Pi_M^N, \Pi_M^{RS} = 0.60\Pi_M^N$, and $\Pi_R^{MS} = 0.59\Pi_R^N, \Pi_R^{RS} = 1.10\Pi_R^N$. We unexpectedly observe that the shift of power along the supply chain asymmetrically affects the members' profits. Compared with the balanced power situation, the dominant manufacturer and the retailer earn 16% and 10% more profits, respectively, while as a follower, the manufacturer and the retailer reduce 40% and 41% profits, respectively.

Proposition 7. *The comparison of the supply chain efficiencies in terms of profits between the vertically integrated and the decentralized supply chains is:* $\Pi^I > \Pi^N > \Pi^{MS} > \Pi^{RS}$. *The explicit expression is* $\Pi^{MS} = 0.75\Pi^I, \Pi^{RS} = 0.73\Pi^I, \Pi^N = 0.86\Pi^I$.

Proposition 7 indicates that the highest supply chain efficiency is achieved when the decisions are made by a central manager, which means that the vertically integration always outperforms the decentralization. In a decentralized supply chain, the supply chain efficiency is highest when both members have a balanced power structure. That is, a power transfer to either member would reduce supply chain efficiency. In the case of neither player dominates the supply chain, the manufacturer Stackelberg game model is more efficient than the retailer Stackelberg game model, the difference between which is quite slight (i.e., 2%).

6. Conclusions

The study explores the manufacturer's operational decisions, e.g., wholesale price and product sustainability level, the retailer's operational decision, e.g., retail margin, and supply chain efficiency under three supply chain power structures: manufacturer Stackelberg, Nash and retailer Stackelberg, using analytical model. As a benchmark, we first obtain the equlibrium price and product sustainability level in a vertically integrated supply chain. Key findings in this paper to manage sustainable supply chain are accordingly summarized as:

- a dominant manufacturer (retailer) always benefits from its power;
- the entire supply chain earns the most profit from the Nash game, and the least from the retailer Stackelberg game, respectively;
- as the power shifts from the manufacturer to the retailer, product sustainability and retail price increase;
- power manufacturer does not necessarily imply low wholesale price that would benefit the retailer;
- vertically integration is always the superior choice because it achieves the highest supply chain efficiency.

As pointed out by [12], a player within the supply chain benefits from its power depends on the expected demand model, future research should consider the impact of uncertain demand on sustainable supply chain management. The horizontal competition from either the manufacturer or the retailer layers also deserves to be investigated as well. Moreover, in light of the proposed framework has been employed to unlock impact of uncertain demand [12], service outsourcing [20], quality decision in supply chain encroachment [35], it is reasonable to further extend the present research considering carbon emission sensitive demand.

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