Addressing Sustainable Supply Chain Network Using Stackelberg Game

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Abstract. The importance of sustainability in supply chain contracts is not concealed, and there has been a great deal of effort to address some types of supply sustainability issues. Another issue that has been added to this view today is the issue of risk, which we have addressed in this article as supply risk. We have actually tried to combine two supply contracts such as revenue sharing and buyback with these parameters and link the new concepts to the supply chain. Then, we examine the types of risks and their relationship to supply contracts and develop a model based on which the model somehow expresses the relationship between the two contracts clearly. Finally, by some of the Regression analysis, we examined the existing parameters and their role in profit and change variables. The proposed model used Stackelberg game theory. This area of mathematics focuses on the mutual benefit of the parties to the contract and increases the austerity of both parties. In our model the leader of the game is actually the same supplier.

Keywords: Sustainable supply chain · Stackelberg game · Buy back · Revenue sharing

1 Introduction

In recent decades, dissatisfaction with the global energy crisis has become increasingly popular in the supply chain. Thus, these debates have attracted the attention of many scientists [3] So there is a branch of supply chain called Sustainable Supply Chain Management (SSCM). It is actually about the integration of three dimensions: economic, environmental and social [4, 5].

Many large, multinational corporations, such as Alcoa, PepsiCo, General Electric, Ford Motor, Nike, Exelon, PG&E, Starbuck's, Johnson & Johnson, and Walmart, are implementing sustainable supply chain practices. Wal-Mart has partnered with Patagonia to develop environmentally friendly products to changes "green" businesses [4].

In the food industry, however, sustainability is more serious as the world's largest retailer of natural and organic Whole Foods Market (WFM) tries to show its insistence

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on its suppliers striving for green. In another example, PepsiCo, the beverage giant, announced its Sustainability Focus Program for 2025, focusing on the environment, health and social issues across its supply chain. The company also obliges its suppliers to implement green technology to reduce carbon footprint. Given the examples above, the sustainability problem is specifically caused by the examples above, where an upstream company is attempting to green while a downstream company (either a buyer or a retailer) tries to achieve this. The field is moving slowly. Both players (supplier or buyer) may make these sustained efforts at the same time. However, there are cases of suppliers that attempt green and buyers trying to corporate social responsibility CSR [10, 11]. On the other hand, Downstream companies (buyer/retailer), on the other hand, are likely to face the public directly. Therefore, the buyer tends to make more efforts for CSR to identify itself as a socially responsible agent. So it is better to do this in downstream companies as well.

Recent studies show that investing in green technologies is one of the major obstacles to implementing sustainability [9]. In addition, manufacturing companies are only willing to adopt green technology or CSR activities if they increase their profits. This will only be possible if companies do not ignore their enduring image [8].

The environmental and social implications of the supply chain are increasingly being perceived by stakeholders as being essential to supply chain performance, so a new concept in the supply chain is called risk management. To this end, a growing number of studies have developed theoretical frameworks and analyzed empirical cases to evaluate and improve the economic, social and environmental performance of supply chains. On the other hand, supply and demand problems are another emerging risk. Overall, it can be said that long ordering times, high uncertainty in consumer demand, mismatch between supply and demand are one of the most important concerns in many industries [25, 26].

Among the most significant past and future risks in the industry may include managerial and economic events in Europe and the US, fires at Philips semiconductor workshop equipment in New Mexico leading to Ericsson's exit from the mobile market, fuel crisis and attacks Terrorist pointed out. In this paper, we examine a model of two supply contracts that almost all industries deal with, namely the risk sharing & Buyback contracts, while also considering sustainability elements from a supply-risk perspective, which in turn It is one of the most important global concerns.

2 Literature Review

In this part, we review related literature. First we review the related literature of sustainable supply chain. Subsequently, we review the extant literature on different important part of SSCM.

2.1 Sustainable Supply Chains

Taxonomical classification and detailed literature reviews of SSCM have been carried out by various scholars [1, 2, 7]. Most of these papers suggest that mathematical modelling has been given less attention. As per Ashby et al. [2], less than 25% surveys papers used quantitative techniques in SSCM. Reefke et al. [13] argued that simultaneous consideration of all the three dimensions in the analytical models is a challenge and is required to be investigated. most of papers consider only economic aspect in analytical models while a few studies have additionally considered only greening aspect in their analytical models. Ghosh et al. [10, 11] analysed a dyadic green supply chain using game theoretic approach. Authors have shown how SC agents decide their decision variables when only the supplier puts greening effort in the supply chain. Zhu et al. [27] have extended the green supply chain model to a green supply chain network consisting of one manufacturer and two suppliers and have explored the impact on greenness due to competition between suppliers.

None of the aforementioned studies considers social impact in their analytical models and its influence on SC coordination. In recent past, some papers [6, 12, 14–16] have prepared analytical models of socially responsible SC. Two different approaches have been adopted to incorporate social aspect in the SC models in extant literature. Few scholars [6, 14, 15, 17] have examined social dimension in the form of consumer surplus, and the Others have incorporated the social dimension as efforts put by SC agents. Ni and Li [16] have analysed a dyadic supply chain under CSR aspect using simultaneous and sequential move games.

In this paper we want to compare two most common agreement in supply chain, with greening aspect of it. Our study is closely related to Ghosh & Shah [10, 11, 14] who have respectively examined the impact of greening and CSR on SC coordination. Also, Our study differs from these scholars as we consider simultaneous aspects of greening in our model and the same is so far unreported in the extant literature.

2.2 Supply Chain Risk of Management

Today's business environment is constantly changing and changing is all about risk. No company is immune from change and related events. As companies move toward global supply-chain modeling and supply chain modeling, the result will be a longer flow of goods, a shift in customer delivery times, a shorter product life span, and customer expectations [14].

A survey by McKinsey's survey of 1,500 managers from 90 countries shows that these managers show extreme levels of risk aversion regardless of size of investment [18]. Therefore, factors in supply chains are not necessarily neutral. Various risk measurements have been introduced in supply chain management to depict the decision behaviour of decision makers that are risk averse, such as downside risk [19], value at risk [20], loss aversion [21], and mean variance [22].

Risk management in the first stage avoids risk occurrence and, if risk avoids, minimizes losses and increases pre-occurrence preparedness. Some authors have added a third purpose, which points to a way to deal with the risk that has occurred. In fact, risk management is a way of preventing, reducing, transferring or sharing risk [23]. These two authors define supply chain risk management as "a collaborative process in which supply chain members use management process tools". Risk avoids the uncertainties created by logistics-related activities. However, there is no agreement yet on a comprehensive definition of supply chain risk management.

Hendricks et al. [24] conducted an empirical study of the negative impacts of accidents and interruptions on supply chain operational performance. Their first findings were on the company's profitability and cash flow. Authors found that companies averaged 6.92% in sales growth, 10.66% in costs, and 13.88% in inventory turnover. Hendricks examined the negative impact of risk on the value of corporate stocks. The results show that risks reduce the value of the stock by an average of 10.28%. Poor risk management also has a detrimental effect on company reputation, customer relationships, employees, suppliers and other stakeholders in the supply chain. Previous risk management approaches have weaknesses and shortcomings that cannot be used as an efficient tool for managing events and disruptions in the supply chain. As awareness of the shortcomings of risk management approaches increases, many supply chain researchers have begun their studies to find a way that is capable of dealing with future unknowns. According to these studies supply risk could be one of the most important risk in coordination and we prepare it in our model for first time.

2.3 Stackelberg Competition

Stalkberg game in game theory is a non-participatory strategy game and is a dynamic game with complete information Which is very useful in supply chain optimization under Vendor managed inventory policy. In Stalkberg, players are divided into leader and follower categories. This game is done in two stages. In this way, first, the leader determines its variables by knowing the advantage of the best response of the follower, and then, the follower calculates the value of his decision variable to maximize the profit by considering the values provided by the leader. So they come to Stackelberg equilibrium. In equilibrium, neither will be eager to change the situation, because the equilibrium point creates the greatest benefit for each [29].

Because of the competitive nature of contracts and the competitive environment between their stakeholders, as well as because that the proposed model is a competitive supply chain, the Stackelberg game method is used to create a competitive environment between the parties and so paves the way for determining the winner.

3 Model

In this paper we consider a supply-based risk structure that is similarly replicated in both contracts. Also, in order to reconcile the contracts with the sustainability issue, a sustainability factor is considered as the acceptance factor as well as a sustainability cost (seller's).

We also consider a deterministic linear demand function faced by a buyer in the market as follows: $q = A - BP + \alpha\theta$ (A, B, α) where, a is overall market potential, B is own-price sensitivity, P is retail price, q is order quantity, θ is greening level, α is e consumer sensitivity to greening.

According to game theory, At the beginning of the period, the supplier moves first, chooses her corresponding parameter(s) in both contracts, and greening level (θ) for the product. Subsequently, the buyer have her own acpects. The buyer pays the supplier through the relevant transfer payment function. Now, we start to introduce our model of contracts with these Hypothesizes. All relevant notations used are presented in Table 1.

Table 1. Notations used

	Notations	Meaning/Explanation
Decision variable	p	Unit selling price of the buyer
	q	Order quantity
	θ	Sustainability level
	w	Wholesale price
	k	Percentage of revenue sharing
	b_y	Buyback price
	R	Return percentage of products
Demand parameters	A	Market potential
	B	Consumer sensitivity to price
	α	Buyer's sense of sustainability (greening)
	D	Product demand
Cost parameters	C	Producer sale price
	Π_B	Buyer profit rate
	Π_S	Supplier profit rate
	I	Cost of sustainable investment (vendor response)

3.1 Revenue Sharing Model

The model considered in this section is actually inspired by [28] paper model which is tailored to the research assumptions underlying the basic paper model as well as the limitation in terms of risk taking has been added.The optimization problem for the supplier, according to revenue sharing, can be formulated as follows:

$$Max \quad \Pi_S = \underset{W,\theta}{Max} = \{(1-K)Pq + (w-C)q - I\theta^2\} \tag{1}$$

$$q = argmax\ \Pi_B = \{(kP + (P-w))q \geq \overline{\Pi}_B \tag{2}$$

$$\Pi(S) = (1-k)Pq + (w-C)q - I\theta^2 \geq \overline{\Pi}_S \tag{3}$$

$$q = A - BP + \alpha\theta \tag{4}$$

$$A - Bw \geq 0 \tag{5}$$

According to Eqs. (1) to (5) and its explanations, it can be said that the constraint is in fact the objective function, and as previously explained, according to the Stackelberg model, the seller was chosen as the leader, and This is why the target function is used to maximize the leader's profits. Once the leader has increased his target parameters, it depends on the follower (who is actually the buyer), where limit 2 actually determines his profit margin. Constraint 4 actually specifies the amount of output that, due to the stability considered in the model, attempts have been made to include elements of stability in the model. Finally, Constraint 5, which is one of the model innovations for considering product risk, plays an important role in understanding the model and reducing risk.

3.2 Buyback Model

The Buyback contract model is actually a completely innovative model with different definitions in supply chain contract design books, and it has also been attempted to incorporate the structural format of the model with respect to the revenue sharing model to allow better comparisons. At the end of the model, the definitions and logic of each constraint are fully incorporated. The following model is conceivable.

$$Max \prod_s = \underset{w,\theta}{Max} = \{(w - C)q - b_y(q - D) - I\theta^2\} \tag{6}$$

$$q = \underset{q,b_y}{argmax} \prod = (P - w)q + b_y(q - D) \geq \overline{\prod}_B \tag{7}$$

$$\prod_{(S)} = \{(w - C)q - b_y(q - D) - I\theta^2\} \geq \overline{\prod}_S \tag{8}$$

$$q = A - BP + \alpha\theta \tag{9}$$

$$(q - D) \leq Rq \tag{10}$$

$$w \geq b_y \tag{11}$$

$$R \leq 1 \tag{12}$$

In this type of contract, although there are a number of repetitive constraints, but to maintain the spirit of the contract, its type must be considered. As you can see, constraint 6 is actually a function of the purpose of the contract written by the producer leader. Constraints 7 and 8 are the same as the revenue sharing contract and have not made any significant changes to their internal divisions, with the addition of demand variables and the return price of unsold products added. Constraint 9 is in fact feasible (from revenue sharing contract). But in the case of constraint 10, a mechanism must be considered so that the buyer does not unrealistically and logically order the restriction to actually control it. Constraint 11 also states that the return price of the product is less than the total selling price so as not to harm the seller. Finally, constraint 12 states that The percentage of return on the unsold product must be less than 100% of the product.

4 Analysis and Findings

In this chapter, by analyzing the sensitivity of various parameters in the model and considering all aspects, we reach the following results:

- According to all analyzes, the three parameters ΠB, A and B have the greatest impact on the two contracts.
- Parameter A has the greatest impact on the objective performance of both contracts. So we conclude that there is a need for more market potential for more profit.
- Among the decision variables, first the price variables (W and p) have the most impact, respectively, and then the q variable have the most impact, respectively.
- To consider the risk in terms of analysis results, it is better to use price variables.
- According to these analyzes and the contracts concluded in the business world, it is better to use a more revenue-sharing contract in the financial sector and a redemption contract in the production sector. One of the reasons for this decision could be the effect of the parameters ΠB and Πs in the buyback agreement.
- In both contracts, the ΠB parameter had the most negative impact on the objective function.

5 Numerical Analysis

In this section we want to show our analysis using regression method. in this case, We also need Basis numbers for parameters. for this purpose, we search for these parameters to accept the best ones.

According to [28], we found some more information about best optimal parameters. However, because the proposed model has different parameters than the reference article, to determine the values of some of the parameters, we ran our model in Matlab programing and used different values and checked the results of these values. Therefore, the following parametric values are considered for numerical analysis: A = 100, C = 5, D = 50, I = 2, B = 1, $\alpha = 0.05$, $\Pi_{B =}$ 528, $\Pi_S = 1557$. In Fig. 1, we have mentioned Significance level of the most important parameters. First we start with revenue sharing contract.

5.1 Revenue Sharing Analysis

In this contract, we examine almost all the parameters and finally reach the most important ones. One of these parameters is A, which has a significant relationship with P, q and the objective function as evident in Figs. 1, 2 and 3. Another parameter that has a significant relationship is α. Obviously, there is a good relationship between α and θ as illustrated in Fig. 4.

5.2 Buyback Analysis

In the buyback agreement, despite the demand in the equations, we see that this parameter has no significant effect on the improvement of the contract and can only be used as a part of the contract. In this type of contract, only the parameter (ΠS) has a significant relationship with changes in the objective function, which can be deduced from Fig. 5.

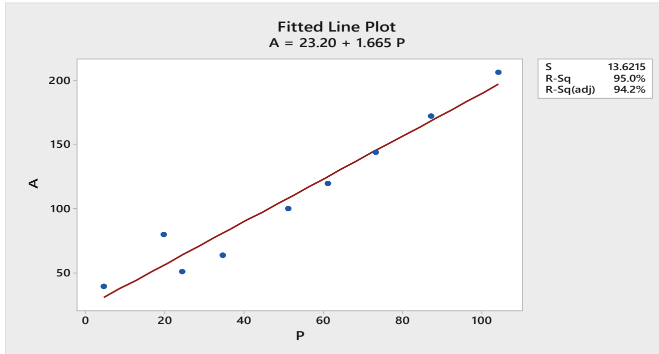

Fig. 1. Regression graph for variable P in revenue sharing contract

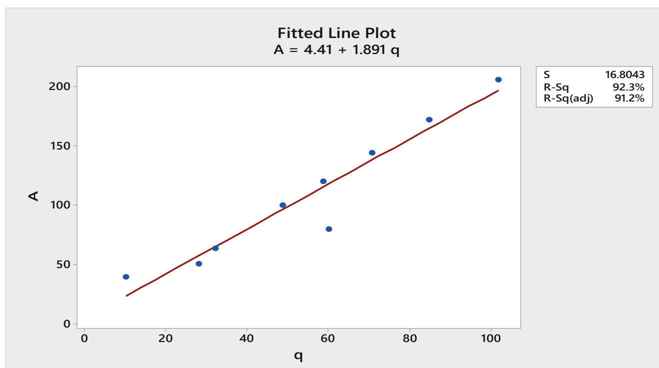

Fig. 2. Regression graph for variable q in revenue sharing contract

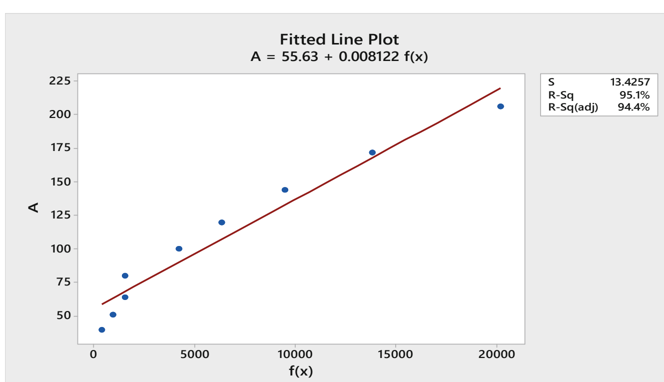

Fig. 3. Regression graph for function in revenue sharing contract

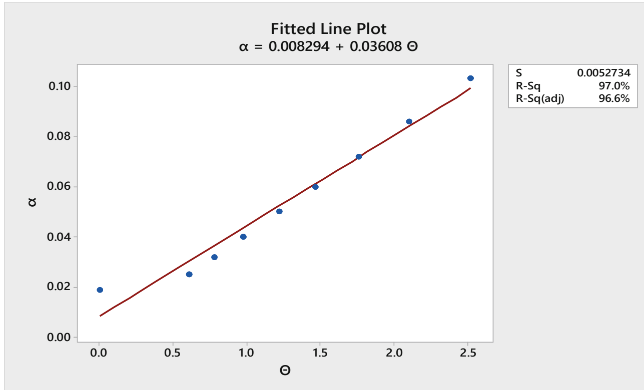

Fig. 4. Regression graph for variable θ in revenue sharing contract

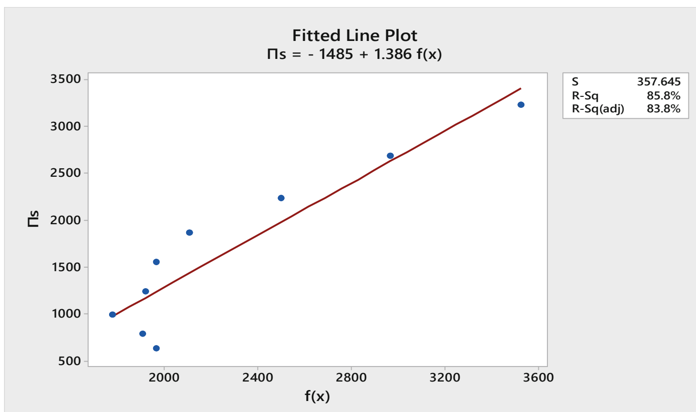

Fig. 5. Regression graph for function in buyback contract

6 Conclusion and Future Works

In this paper, we have designed a sustainable SC model by simultaneously considering greening and supply risk efforts of SC agents. Subsequently, we have analyzed two supply contracts in this setup. To the best of our knowledge, such analytical model is hitherto unreported in the extant literature, especially buy back contract. In this context, we have first analyzed two specious of contracts. We attempted to compare them for first time. They are almost most useful contracts for every industry. We have presented the analytical results for each of them. We obtained the optimal contract parameter(s), order quantity, retail price, greening level, supplier's profit, and also, buyer's profit. We have also numerically compared the optimal decisions for these supply contracts. We have also illustrated all the important issues to use in real industries. Our study indicates that it is better to use buyback contract for productive industries and use revenue sharing in a financial way.

Analysis shows that 3 parameters such as A, B and Π_B is more important than others. In decision variable we should be watchful about any price, in particular W and p because they have more impact than others on function and parameters.

In the end, we would like to enlist few limitations of our model and possible future research opportunities. It is recommended that the contracts be dissolved in different ways in order to continue working in this field and that the best one be chosen. It is also possible to quantify the risk assumed to determine its exact value.

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