CONSIDERING COOPERATION CONTRACTS IN THE SUPPLY CHAIN OF PERISHABLE GOODS USING GAME THEORY


Khalafi, S
Department of Industrial Engineering, Faculty of Industry, Islamic Azad University, South Tehran Branch, Tehran, Iran

Hafez Alkotob, A
Associate Professor of Industrial Engineering, Faculty of Industry, Islamic Azad University, South Tehran Branch, Tehran, Iran
a_hafez@azad.ac.ir

Mohammadi Tabar, D.
Assistant Professor, Department of Industrial Engineering, Faculty of Industry, Islamic Azad University, South Tehran Branch, Tehran, Iran

Sayyadi, M.K.
Assistant Professor of Industrial Engineering, Faculty of Industry, Islamic Azad University, South Tehran Branch, Tehran, Iran

Resumen: En diversas actividades de componentes y niveles de una cadena de suministro para mejorar el estado general del sistema, se observan muchas contradicciones entre los objetivos de los componentes y los distintos niveles en el logro de los objetivos globales de la cadena de suministro que, con el tiempo, contribuyen a la reducción de la potencia y la competitividad de la cadena de suministro. La interacción entre las dos partes de la cadena de suministro determina aspectos tales como el tamaño del lote, la cantidad de la orden, el precio de la oferta y el precio final. Cada uno de los puntos anteriores se discute en el proceso de negociación de las partes y los contratos finales se alcanzan en cumplimiento de los objetivos de cada una de las partes. Existe una pléyora de modelos para resolver problemas y problemas de interacción entre minoristas y productores de la cadena de suministro considerando muchos factores, tales como factores de coste o cuestiones relacionadas con los principios de competencia entre las dos partes. El uso de la teoría de los juegos para crear una cooperación entre las partes en la cadena de suministro conduce a la determinación del punto de equilibrio, en el cual el tamaño óptimo del lote, el precio de la oferta, la cantidad de deficiencia, considerando los movimientos y las consecuencias de cada parte. Además, y desde otro ángulo de la cadena de suministro, la cadena de suministro de productos perecederos ha sido siempre uno de los temas más importantes y desafiantes de la gestión de la cadena de suministro en momentos diferentes. El diseño adecuado de la cadena de suministro tendrá un impacto óptimo en el rendimiento del sistema, ya que un diseño inadecuado causará muchos problemas. La pérdida de bienes, además de ser perjudicial económicamente para las empresas, aumenta los daños ambientales y conduce a una mayor contaminación del medio ambiente.

Palabras clave: Cadena de Suministro, Contratos de Cooperación, Mercancías Perecederas, Teoría de Juegos

Abstract: In various activities of components and levels of a supply chain to improve the overall state of the system, many contradictions are seen between the objectives of the components and the various levels in achieving the overall goals of the supply chain, which, over time, contribute to a reduction in the power and competitiveness of the supply chain. The interaction between the two parts of the supply chain determines items such as batch size, order quantity, bid price, and final price. Each of the above points is discussed in the bargaining process of the parties and the final contracts is reached in pursuance of the goals of each of the parties. A plethora of models exists in solving problems and interaction issues between retailers and producers in the supply chain considering many factors, such as cost factors or issues related to the principles of competition between the two parties. The use of game theory to create cooperation between the parties in the supply chain leads to the determination of the equilibrium point, in which the optimal batch size, the bid price, the amount of deficiency, as well as the optimal final price are determined by considering the moves and consequences of each party. Moreover, and from another angle of supply chain, the supply chain of perishable goods has always been one of the most important and challenging issues of supply chain management at different times. Proper design of the supply chain will have optimal impacts on the performance of the system, as inappropriate design will cause many problems. Perishing of goods, in addition to being economically damaging to enterprises, increases environmental damage and leading to further pollution of the environment.

Keywords: Supply Chain, Cooperation Contracts, Perishable Goods, Game Theory

1. INTRODUCTION

In recent years, many researchers and artisans have focused on the supply chain. A supply chain is a set of methods used for effective integration and efficiency of suppliers, manufacturers, distributors, and retailers to minimize costs of system, production, and distribution of goods as many as needed at the right time and place and meeting customer needs. In this regard, supply chain is managed to achieve the best combination of responsiveness and efficiency for market success (Kovačić, D., et al, 2015).

This paper examines the two-tier supply chain and the relationship between producer and retailer. This particular mode represents a manufacturer that sells its product massively to retailers and delivers the product to customers as well. In each supply chain, there is a close interaction between the two levels. This paper has considered the relationship between these two parts as a kind of game to determine each of the above-mentioned points in the process of interaction between producer and retailer. In this game, each player (whether producer or retailer) wants to reach the point at which they get the highest outcomes due to their movements, as well as the consequences of each move of themselves and the opponent. Using the game theory approach, this goal, which is the game's equilibrium, is examined using the non-cooperative game method. The paper states the problem, reviews the literature, and then performs indexing. Later on, the paper introduces the variables of the model, presents model hypotheses and objectives functions of both players - manufacturer and retailer - and finally, with the theory of non-cooperative games obtains the balance between the retailer and the producer.

2. PROBLEM STATEMENT

The primary goal of each supply chain is to meet the needs of customers, and the outcome of this process is earning profits and revenues for the producer and other elements involved in the chain. In general, the movement of materials from suppliers to manufacturers, and then to distributors and retailers, and ultimately to customers throughout the chain illustrates the flow of supply chain activities. Here, the display of information and financial flows throughout the chain is of great importance. In a supply chain, a manufacturer may supply the raw material required from several suppliers rather than from one supplier and, on the other hand, send its products to a large number of distributors. Therefore, many supply chains are in the form of supply networks. Moreover, the supply chain is a network of organizations that deal with upstream downstream processes and activities and value the products and services provided to the final customer. The goal of all those involved in the supply chain is to increase the competitiveness or increase of customer service because today, from a final customer perspective, an entity alone is not responsible for the competitiveness of its products or services, and the supply chain of all organizations involved together; considering these issues, companies competition move towards supply chains (Kovacic D, and Bogataj M 2013).

In recent years, many researchers in the food supply chain have focused on the importance of supply chain management (Khani, M. 2009). Providing healthy and quality food, especially those with more specific conditions, such as perishable goods, is one of the concerns of the companies of these supply chains (Morganti, E., & Gonzalez-Feliu, J. 2015).

Dangers of food can occur at each stage of the food supply chain, making it necessary to determine the critical control points for information on materials, construction, expiry dates, etc., and to provide it in a transparent manner for participants and suppliers of the supply chain (Li, Y., & Zhao, D. 2014). In the food supply chain, specific circumstances of the chain, such as climatic conditions, seasonality of raw materials, perishing at specified times, and special storage conditions lead to more uncertainties (Lee, H., & Whang, S. 1999).

Based on the studies, complex supply chain of food industry is constantly changing. Changing food
preferences, shopping habits and lifestyles increase pressure for easy preparation of products. Furthermore, demographic developments have led to higher demand for fresh products and products with high value added. In addition, given the variety of products in the market, the challenge of predicting and responding to customer demand for manufacturers and retailers is even more important. In addition, manufacturers and retailers must focus more on managing delivery times to grant customer satisfaction. Thus, given the importance of the discussion of food-supply chain and the challenges that exist in this field, such as customer demand changes, delivery times, inventory shortages, etc., and given that perishable foods have more specific conditions compared to non-perishable food, managing supply chain of perishable foods becomes more important. This is because if the products do not reach the customer in a timely manner and corrupt during the cycle, great costs will be imposed on the entire supply chain. The importance and emphasis on competition and collaboration in supply chains have revolutionized the theory of games as an ideal tool for analysis of the actions in the supply chain. Supply chain players compete to improve their profits and performance. For example, multiple factors can compete among members of a chain, such as resource constraints, competition for customer demand, and others. Supply chain members may have to have a commitment and contract to coordinate their strategies to improve the overall system performance. Naturally, a primary methodological tool for examining these issues is the theory of non-cooperative and cooperative games that focuses on sequential or simultaneous decision-making by players under conditions where 2. The two sides, known to the players, should have conflicting interests.

3. Each player tries to win and achieve a further outcome, but the victory or defeat of a player is not only dependent on his own efforts, but depends on the opponent's movements (Abdoli, Q. 2007).

**System structure**

In this research, closed-loop supply chain system is considered similar to dairy systems, including manufacturer and retailer as shown in Figure 1.

![Figure 1. The schematic diagram of the supply chain discussed](image)

The other thing about the model is that the manufacturer initially declares the price to the retailer and, based on the price offered, the retailer can decide on its size and economic order.

### 3. LITERATURE REVIEW

Many studies have been conducted on the supply chain of perishable materials and the solutions to them, which is summarized in Table 1.
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Table 1. Background and research records
For the modeling of the supply chain, the following assumptions are considered and the parameters and variables of the research are shown in Table 2.

1) An unlimited period of planning is considered.

2) The deterministic and predetermined model parameters are considered.

3) Inventory and maintenance costs are considered high for the manufacturer.

4) The annual demand depends on the sale price.

5) A shortage of authorized inventory systems is considered, and for each deficit item, there are penalties for defective costs.

### 4. Retailer model

The retailer’s goal is to determine the amount of sales price and marketing costs in a way that maximizes its net profit. The selling price affects the amount of demand, and consequently the size of the manufacturer’s category will change. Therefore, the annual profit function for retailers will be as Relation 1. In the following, the profitability of retail sales in the two-tier supply chain is derived from the difference in sales revenue from the cost of buying, ordering and storing goods (Esmaeili, M., et al, 2008).

\[
P_{r}(P) = (P \cdot D) - (C_{p}(B) \cdot \frac{D}{Q}) - \frac{1}{2} iP_{0}Q
\]

(1)

We place the amount of demand according to

\[D = f(P) = K \cdot P^{-\alpha}\]

in the above function, and the above relation will change as 2:

\[
P_{r}(P) = (K \cdot P^{-\alpha}) - (K \cdot P^{-\alpha}) - \frac{1}{2} iP_{0}Q - (C_{p}(B) \cdot \frac{K \cdot P^{-\alpha}}{Q})
\]

(2)

We derive from the above function in terms of product price and set it equal to zero. Assuming the other variables as constant, we will have the final price value for retailers in the form of Relation (3):

\[
\frac{\partial P_{r}(P)}{\partial P} = 0 \rightarrow P^{*} = \frac{\alpha \cdot (P_{0} + C_{p}(B))}{\alpha - 1}
\]

(3)

### 4.2. Manufacturer model

The manufacturer’s goal in interaction with supply chain retailer is to determine batch optimal size and the suggested price to the retailer in such a way as to maximize its profit in the supply chain. With the development of Abed & Weng (1998) model and adding batch size to their model, the net profit of the supplier can be calculated as follows (Relation 4).

We replace demand

\[
P_{r}(P_{0}, Q) = (K \cdot P_{0} \cdot P^{-\alpha}) - (K \cdot C_{p}(S) \cdot P^{-\alpha}) - (\frac{K \cdot C_{p}(S) \cdot P^{-\alpha}}{Q}) - (\frac{iC_{p}(S)(Q-b)^{2}}{2Q}) - (\frac{K \cdot C_{p}(S) \cdot b \cdot P^{-\alpha}}{Q}) - (\frac{C_{p}(S) \cdot b^{3}}{2Q})
\]

(5)

By assuming the manufacturer's bid price constant and making the derivation of the profit function obtained equal to zero in Relation (5), we will calculate the ratio of the size of the economic order, the optimal amount of the economic order (batch size) as well as the optimal
amount of deficiency for the producer as follows (Haj Shir Mohammadi, A. 2007).

\[
\frac{\partial P_b(P_o, Q)}{\partial Q} = 0 \Rightarrow Q^* = \frac{2D(C(S)) + (iC_b(S))}{iC_b(S)}
\]

(6)

\[
\frac{\partial P_b(P_o, Q)}{\partial b} = 0 \Rightarrow b^* = \frac{2D(C(S))C_p(S)}{C_p(S)[(C_b(S) + (iC_p(S))]
\]

(7)

We place the above value in the producer's profit function and set it to zero, the price of the producer to the retailer, in which the producer's profit is zero, can be calculated as Relation 8:

\[
P_b^* = R.P_o \quad \text{IF} \quad R > 1
\]

5. SOLVING THE MODEL USING GAME THEORY

In this section, the interaction between the manufacturer and the retailer is considered and examined as non-cooperative game by Stackelberg. In the non-cooperative game of Stackelberg, one of the players dominates the other and is somehow played in a dynamic and sequential manner, and one of the players has the advantage of delay in the move (Osborne, Martin J., 2004).

5.1. The producer's non-cooperative game model of Stackelberg

In this case, the manufacturer is a pioneer and the retailer has a following role. In proportion to the value of the proposed price and the size of the specified category by the manufacturer, the customer should receive the best final price and marketing cost according to the manufacturer's actions and the model. In this case, the producer seeks to maximize his profit but based on the final and optimal retailer's price, which in some way expresses the best responses of the other player (Osborne, Martin J., 2004), so the mathematical model of the problem will be based on the objective function and its constraints are as follows:

MaxZPr(P_b, Q) = (KP^b) - (C_b(S)) - (\frac{1}{2}JP(Q) - (C_b(B)(K.P^b)).

Subject To:

Q = \frac{2D(C_b(S)) + (iC_b(S))}{iC_b(S)}

b^* = \frac{2D(C_b(S))C_p(S)}{C_p(S)[(C_b(S) + (iC_p(S))]

P_b^* = R.P_o \quad \text{IF} \quad R > 1

P_o, Q, b > 0

In this model, based on the target function calculated, the retailer seeks to maximize his profit based on the manufacturer's bid deficiency, and the final price of the product are obtained.

5.2. The retailer non-cooperative game of Stackelberg

price and order batch size.

MaxZ P_o(P) = (KP^b) - (C_b(S)) - (\frac{1}{2}JP(Q) - (C_b(B)(K.P^b)).

Subject To:

Q = \frac{2D.C_b(S)}{i.C_b(S)} \times \frac{C_b(S) + (iC_b(S))}{C_b(S)}

b^* = \frac{2D.C_b(S)C_p(S)}{C_p(S)[(C_b(S) + (iC_p(S))]

P_o^* = R.(C_b(S)) + (C_b(S) + (iC_b(S)) \left[\frac{C_b(S) + (iC_b(S))}{Q} + \frac{[C_b(S) + (iC_b(S))]}{2KQ.P^b}\right]

P_o >= 0

Solving two non-linear programming models above with the aid of MATLAB software calculates the equilibrium of the retailer-producer game, and the unknown values of the producer's initial price, the amount of the economic order, the amount of

P_o = [C_b(S)] + \left[\frac{C_b(S) + (iC_b(S))}{Q} + \frac{[C_b(S) + (iC_b(S))]}{2KQ.P^b}\right]

Given that the profit function for the producer is a linear and upward function, the optimal point in such a function is at the highest price that the manufacturer can offer to the retailer. Therefore, the optimum price offered by the manufacturer to the retailer is as follows:

P_o^* = R.P_o \quad \text{IF} \quad R > 1

With sensitivity analysis of the above models relative to , one can measure the sensitivity of the model to this parameter. By plotting the producer and retailer's profit functions according to this parameter and changing the parameter value, one can determine the sensitivity of the two-level supply chain objective functions relative to this parameter. This paper examined the challenge between producer and retailer in a two-tier supply chain and used game's theory with non-cooperative approach to solve the challenge. Since there are different categorizations for games, one can examine non-cooperative strategy of this paper with other game theories, such as static game with full information, static game with incomplete information, dynamic game with full information, and cooperative game as well as

6. CONCLUSION

With sensitivity analysis of the above models relative to , one can measure the sensitivity of the model to this parameter. By plotting the producer and retailer's profit functions according to this parameter and changing the parameter value, one can determine the sensitivity of the two-level supply chain objective functions relative to this parameter. This paper examined the challenge between producer and retailer in a two-tier supply chain and used game's theory with non-cooperative approach to solve the challenge. Since there are different categorizations for games, one can examine non-cooperative strategy of this paper with other game theories, such as static game with full information, static game with incomplete information, dynamic game with full information, and cooperative game as well as
dynamic game with incomplete information and calculate and analyze solutions such as Nash equilibrium, dominant balance, poor equilibrium, recursive equilibrium, or sub-game equilibrium.

The demand function used in the model has only considered dependence of demand on the product part as the demand pull factor. However, in perishable products industry, in particular dairies, in addition to the final price of the product, other factors, such as the level of freshness of the product affect the demand for the product. Thus, in future research, the researchers can consider the demand function in a more sophisticated and realistic way to establish cooperation in the supply chain with the game theory approach.

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