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Study on the complexity pricing game and coordination of the duopoly air conditioner market with disturbance demand

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ABSTRACT

The paper focuses on the dynamic pricing game of the duopoly air conditioner market with disturbance in demand and analyzes the influence of disturbance on the dynamic game system. Considering the demand for products, such as air conditioner, varies with different seasons, we assume three cases based on the condition of disturbance, including growth market (Case 1), declining market (Case 2) and completely random market (Case 3). By analyzing these three cases and making comparison among them, the paper shows that the growth market is more sensitive to the changing parameters such as the adjustment variable and the competitive factor than the declining market. It is more difficult to keep the system stable in a growth market. Although the demand is completely random, the dynamic system can reach a stable state, on condition that the adjustment variable is small enough. The results also indicate that the bullwhip effect between the order quantity and the actual demand is weakened gradually along with the price adjustment.

1. Introduction

The demand can hardly remain constant due to the complexity of market. The natural disaster, such as the drop in temperature, epidemic disease, can cause the disturbance in demand. As to the seasonal product, it is common that the market demand is variable. In this paper, we focus on the air conditioner market, which is characterized by the high demand in summer and slack demand in winter. The demand of air conditions changes with different seasons. Specifically, the growth market ranges from winter to summer and the declining market ranges from summer to winter, such that the disturbance in demand should not be ignored. In China, two giants in the appliance retailing market, Gome and Suning, hold of more than 45% of the air conditioner market share. In this paper, we aim to investigate the pricing game of the duopoly market with disturbance in demand, and analyze the influence of the disturbance on the game system.

The existing literature related to the disturbance is mainly on the static game with one retailer and one manufacturer. Qi et al. [1] analyzed the influence of disruption in demand on a supply chain with one manufacturer and one retailer, establishing four cases based on the disruption. For each case, the optimal decision is presented and the coordination mechanism is proposed. The results show that, in the model with one retailer, the critical condition on the relationship between the order quantity and the actual demand is determined by the values of the disturbance and the competitive factor. Xiao et al. [2] extended the analysis of [1], analyzing the disruption on both the demand and the cost in a supply chain with one manufacturer and two retailers. Lei et al. [3] derived the optimal contract for the supplier and showed the impact of asymmetric disruption information on the performance

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of the supplier, with disruption in both demand and cost. Hu et al. [4] considered a supply chain including one retailer and two suppliers under random demand and random yield, and presented the coordination method for the supply chain with random parameters. Chen and Xiao [5] examined a supply chain with a dominant retailer and analyzed the coordination mechanism in condition of the disruption on demand. He and Zhao [6] studied a market with uncertain demand, and found out the method to coordinate the supply chain. Zhang et al. [7] presented revenue-sharing contracts to coordinate a one-manufacturer two-retailers supply chain with demand disruptions. Seifbarghy et al. [8] considered a two level supply chain consisting of a manufacturer and a retailer, designed retailer's revenue sharing contract to coordinate the supply chain. Palsule and Omkar [9] designed a contract to coordinate the profits among the players in supply chain. In view that the game is dynamic and the disturbance changes frequently in the air conditioner market, the analysis on static game is not enough for the disturbance coordination. It is essential to investigate the influence of disturbance on optimal decisions of the dynamic game.

The dynamic game analysis centers on the stability of the system. Agiza et al. [10] studied the complexity of the duopoly game based on bounded rationality of players, and examined the influence of the speeds of adjustment on the system stability. Yassen and Agiza [11] analyzed a Cournot duopoly game when the players are delayed bounded rationality, finding that if the players use different production methods, the stability region of system will decrease. The delay will make the system's region of stability increase. Tomasz [12] analyzed the heterogeneous Cournot duopoly game with bounded rational, in which the two players have different adjustment models. Ma and Mu [13] studied the relationship between the land supply and the housing price, and analyzed the dynamic characteristic of the real estate market. Chen et al. [14] addressed the triopoly 3G telecommunication market and the stability of the system. Ahmed and Elettreby [15] analyzed a multi-market Cournot model and presented the chaos control method for the model. In a dynamic game, the delay decision will exert great effect on the system. Qu and Wei [16] studied the asset pricing model and analyzed the stability of the system in terms of the time delay by using the complex theory. Ma and Wu [17] examined the influence of delayed decision on the stability of the system and demonstrated that the delayed decision can expand the stable region of the system. Li and Ma [18] applied the delay decision to the dual channel supply chain, and identified that as delay parameter increases, the system tend to transit from a chaotic state to stable state, then to a chaotic state once again. Ma and Sun [19] investigated the pricing strategy in a risk-averse supply chain and discuss the effect of decision parameters on the manufacturers and retailer. They found that higher adjustment speed is beneficial for retailer, but harmful for manufacturers.

Most of the existing literature on the dynamic game makes the assumption that the market is stable, under which the equilibrium state of the model can be easily obtained. However, the market is unlikely to remain static. In the dynamic game, the retailers can hardly know the size of the disturbance at the beginning of one period. Furthermore, the disturbance will change again when they get at the better understanding of it. Therefore, it is critical to explore the influence of the disturbance in a dynamic game model and the features of the dynamic system.

2. The basic model

Before the analysis on the dynamic game, we focus on the static model first, which is the basic of the dynamic game. As the common Cournot model, the demand is affected by its own price and competitors', just like the function given by Huang and Swaminathan [20]. Amin-Naseri and Khojasteh [21] analyzed the risk-averse behavior of the players with demand uncertainty, compared the effect of the different leader in Stackelberg game on the system. In this paper, we consider the random variation in demand. The demand model considers disturbance can be written as Eq. (1):

$$q_i = a_i + \Delta a_i - b_i p_i + k_i p_j \tag{1}$$

where q_i, a_i and p_i represent the sales volume, market potential and sales price of retailer i respectively. The parameter with a subscript j represents that the parameter belongs to the competitor of retailer i. For example, p_j represents the price of the competitor of retailer i. The coefficient s b_i and k_i are the price-sensitive factor and competitive factors respectively. When $k_i > 0$, the products of two retailers are substitute products; when $k_i < 0$, they are complementary products. Consider convenience, the retailer's price has a greater influence on its selling quantity than others' prices when the consumer wants to buy the product from this retailer, so $b_i > |k_i|$. The parameter Δa_i represents the random variation in demand. The market scale with random parameter can be written as $a_i + \Delta a_i$. There is no doubt that the market potential must be greater than zero, so $\Delta a_i < -a_i$.

Based on Eq. (1), the profit model can be shown in Eq. (2):

$$\pi_i = (p_i - w) \cdot q_i \tag{2}$$

where, w is the wholesale of manufacturer, which is set to a constant. The retailers will make decision based on first-order conditions of the profit function, that is:

$$\frac{\partial \pi_i}{\partial p_i} = a_i + \Delta a_i - b_i p_i + k_i p_j - b_i (p_i - w) = 0 \tag{3}$$

Solving Eq. (3) and using the parameter with a wave on the top to represent the best solution when considering the disturbance can be written as (4):

$$\tilde{p}_i = \frac{2b_j(a_i + \Delta a_i + b_i w) + k_i(a_j + \Delta a_j + b_j w)}{4b_i b_j - k_i k_j} \tag{4}$$