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The Stability Analysis of Manufacturer-Stackelberg Process in Two-Echelon Supply-Chain

Jie SUa*

School of Management Science and Engineering, Central University of Finance and Economics, Beijing, P.R.China

Abstract

In the two-echelon supply-chain literature, the manufacturer-Stackelberg process, i.e. the manufacturer is a Stackelberg leader and the retailer is a Stackelberg follower, is one of the most common gaming assumptions. In which, the optimal prices and optimal profits of the manufacturer and the retailer should be affected by the shape of the demand curve. In this paper, we discuss the influence to the optimal prices and profits by changing the parameters in demand curve, and analyze the stability of the optimal prices and profits of the manufacturer and the retailer. By using the Lipschitz properties of the optimal price-functions and profit-functions on the parameters of the demand curve, we find that there are sizable distinction in the stability of the optimal prices and profits of the manufacturer and the retailer with different demand curves.

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Keywords: Supply chain management; Manufacturer-Stackelberg process; Stability; Lipschitz property

1. Introduction

The relationship between the manufacturer and the retailer has been investigated by many researchers. The increasing attention to supply chains leads to more studies on mulitiple-echelon systems [1-5].

In the two-echelon supply-chain literature, the manufacturer-Stackelberg process (abbreviated as m-St), i.e. the manufacturer is a Stackelberg leader and the retailer is a Stackelberg follower, is one of the most common gaming assumptions.

In this paper, we will discuss how the changing of parameters in a demand curve affects the optimal prices and profits of the manufacturer and the retailer. And farther, we analyze the stability of the optimal solutions in the two-echelon supply-chain process.

* Corresponding author. Tel.: +86-15300173098; fax: +86-10-62288622.
E-mail address: sujie@cufe.edu.cn.

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2. Preparation knowledge

In this section, some symbols and background materials on the stability in mathematical programming and Lipschitz property of functions are given.

2.1. Basic definitions

In this section, some symbols are given for convenience, and the form of these symbols according to Lau-Lau [3].

Nomenclature

Π Profit. Π may have two subscripted letters and two superscripted letters, e.g., $\Pi_{lR}^{[mS]}$. Π 's two-lettered superscript "$[mS]$" designates for m-St process. Π 's first subscripted letter denotes the demand-curve form; it will be either l for "linear", c for "iso-elastic" or e for "exponen-tial". Π 's second subscripted letter will be either M for manufacture, or R for retailer.

c unit manufacturing cost incurred by the manufacturer.

w unit wholesale price charged to the retailer by the manufacturer.

p unit retail price the retailer charges the consumers.

D_p demand function of p. And D_p 's second subscript denotes different type of the demand function, e.g., D_{pl}.

There are three kinds of demand functions considered in this paper:

- First kind is the linear demand curve $D_{pl} = a - bp$, where a and b are positive parameters, $a/b \geq p$.
- Second kind is the iso-elastic curve $D_{pl} = Kp^{-\alpha}$, where K and α are positive parameters, $\alpha > 1$.
- Third kind is the exponential curve $D_{pl} = \gamma e^{-\beta p}$, where γ and β are positive parameters.

In this paper, we consider the case of one manufacturer selling to one retailer, so their profit functions without logistic cost components are, respectively:

$$\Pi_M = (w-c)D_p,\ \Pi_R = (p-w)D_p \tag{1}$$

So the mathematical model of the m-St process can be described as a bilevel programming problem as follows:

$$\max_{w\geq 0}\left\{(w-c)D_p : p \in \arg\max_{p\geq 0}(p-w)D_p\right\} \tag{2}$$

2.2. Preparation knowledge

In this section, some background material on the stability in mathematical programming and Lipschitz property of functions which will be used later. We give only concise definitions and facts that will be needed in the paper, and there are more detailed information in [6-8].

For the parameter programming problem

$$\max\left\{f(x,t) : x \in S(t) \subseteq \Re^n, t \in T \subseteq \Re^m\right\} \tag{3}$$

We denote R_t^*, f_t^* as the optimal region and the optimal value of problem (3), where t is a parameter. Then we have some definitions on the stability of problem (3).

Definition 1 Problem (3) is called weak stable on parameter $t_0 \in T$, if

1) $R_{t_0}^* \neq \Phi$,