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Some two-echelon supply-chain games: Improving from deterministic-symmetric-information to stochastic-asymmetric-information models

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Abstract

Many supply-chain and inventory models use the following two-echelon symmetric-information and deterministic gaming structure: a "manufacturer" wholesales a product to a "retailer," who in turn retails it to the consumer. The retail market demand varies with the retail price according to a deterministic "demand function" that is known to both the manufacturer and the retailer. It is then assumed that the "players" (the manufacturer and the retailer) arrive at their pricing and batch-size decisions through a Stackelberg game or a "fixed markup percentage" game. The first part of this paper reveals many implausible effects of demand-curve forms on the behavior of these gaming models. However, we do not merely conclude that two-echelon gaming results obtained via assuming one convenient demand-curve form can often become invalid under other demand-curve forms. More importantly, we argue in the second part of the paper that the various implausible effects revealed here suggest a different but more fundamental conclusion: the assumed non-cooperative games are themselves flawed, because "gaming" is meaningless and logically circular in a deterministic-and-symmetrical-information system. We then present an introductory illustration on how the introduction of stochasticity *and* information-*a*symmetry leads to more plausible two-echelon supply-chain gaming models. Together, the two parts demonstrate the necessity and practicality of using a stochastic-and-asymmetric-information instead of the prevalent deterministic-symmetric-information approach in many supply-chain models.

Keywords: Supply chain models; Stackelberg game; Asymmetric information

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1. Introduction

Many recent supply-chain and inventory models (e.g., Arcelus and Srinivasan, 1987; Chopra and Meindl, 2001; Ertek and Griffin, 2002; Li and Huang, 1995; Parlar and Wang, 1994; Weng, 1995a,b, among many others) use the following two-echelon symmetric-information and deterministic gaming structure: a "manufacturer" wholesales a product to a "retailer," who in turn retails it to the consumer. The retail market demand varies with the retail price according to a deterministic "demand function" that is assumed to be known to both the manufacturer and the retailer. How do (or should) the manufacturer and the retailer make their pricing and batch-size decisions? The two most common gaming assumptions in the supply-chain/inventory literature are:

(i) the manufacturer is a Stackelberg leader and the retailer is a Stackelberg follower (hereafter the "manufacturer-Stg" process);
(ii) the manufacturer is a profit maximizer while the retailer applies an openly-declared fixed markup percentage over the manufacturer-imposed wholesale price (hereafter the "fixed-markup" process).

A much less common but apparently equally plausible gaming assumption is the "retailer-Stg" process: the retailer is the Stackelberg leader and the manufacturer is the Stackelberg follower.

For a two-echelon manufacturer-Stg process, Lau and Lau (2003) recently showed that the demand-curve's shape can affect the system's optimal solution in some very counter-intuitive ways, thus demonstrating that results/insights derived from assuming one demand-curve shape cannot be safely generalized to other demand-curve shapes. The first part of this paper (Sections 3–5) extends Lau and Lau's (2003) investigation and reveals other anomalies and counter-intuitive properties for the Stackelberg (both manufacturer-Stg and retailer-Stg) as well as the fixed-markup processes. However, we do not merely extend Lau and Lau's (2003) conclusion; i.e., results pertaining to other two-echelon gaming processes (in addition to the manufacturer-Stg) are affected strangely by demand-curve shapes. Instead, we argue (in Section 6) one step further that the extended anomalies revealed here suggest a very different but more fundamental perspective—the assumed Stackelberg and fixed-markup processes may themselves be flawed. We then conjecture that the assumed gaming processes are implausible because they assume a deterministic system with symmetrical-information, thus making "gaming" meaningless and logically circular. The second part of this paper (Section 7) gives an introductory illustration on how the introduction of stochasticity *and* information-*a*symmetry leads to more plausible two-echelon supply-chain gaming models. Together, the two parts demonstrate the necessity and practicality of modeling stochastic *and* *a*symmetric-information two-echelon supply chains.

2. Summary of some basic and earlier results

2.1. Basic definitions

Define:

Π Profit. Π may have one bracketed superscript (with two letters) and may have up to two subscripted letters; e.g., $\Pi_{l\mathrm{R}}^{[\mathrm{mS}]}$. A non-superscripted Π pertains to an integrated (single-echelon) system. Π's two-lettered superscript "[??]" designates one of the three inter-echelon gaming assumptions considered in this paper: [mS] for *m*anufacturer-*S*tg, [rS] for *r*etailer-*S*tg, and [fm] for a profit-maximizing manufacturer coupled with a *f*ixed-*m*arkup-percentage retailer. Π's first subscripted letter is in italic lower case and denotes the demand-curve form; it will be either l for linear, c for "constant-elasticity" (hereafter "iso-elastic"), or h for "hybrid." Π's second subscripted letter is in non-italic upper case; it will be either M (for manufacturer), R (for retailer), C (for channel, i.e., "manufacturer plus retailer"), or I (for the Integrated firm doing both manufacturing and retailing). Thus, for example, $\Pi_{l\mathrm{R}}^{[\mathrm{mS}]}$ is the retailer's profit (second subscript R) in a *manufacturer*-Stg channel (superscript [mS]) with a