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Interfaces with Other Disciplines

Wholesale pricing and evolutionarily stable strategies of retailers with imperfectly observable objective

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ABSTRACT

This paper develops a one-population (indirect) evolutionary game model of a supply chain with one manufacturer/supplier and many (a sufficiently large number of) retailers to study how the retailer's marketing objective depends on the wholesale price, its observability, the error probability of the observed result on the rival's preference, the market scale and the retailer's bargaining power. This paper also presents an algorithm for computing the optimal wholesale price of the manufacturer. We find that the profit (revenue) maximization behavior is an evolutionarily stable marketing strategy if the wholesale price is sufficiently high (low). Given an appropriate wholesale price, the revenue maximization behavior coexists with the profit maximization behavior in the retailers' population. The larger the market scale, the stronger the motivation of the retailer to take profit maximization behavior due to a higher wholesale price. The cross effects of the retailer's reservation payoff and the other factors should be considered in the decision process.

1. Introduction

A good marketing objective plays an important role in the survival and development (success) of a firm because it will improve the firm's profitability (Neelankavil and Alaganar, 2003). Much of the economics literature assumed that the firm takes profit maximization behavior and did not consider whether the profit maximization behavior is a stable marketing objective. Taking profit (revenue) maximization behavior, the firm will choose a strategy (such as quantity, retail price) to maximize her expected profit (revenue) function given the rival's strategy. However, it has been found that the firm facing competitors can hardly make the highest resulting profit from taking profit maximization behavior (Kaneda and Matsui, 2003; Xiao and Yu, 2006a,b; Smith et al., 1975). For example, a firm will make a lower profit if she sells a smaller quantity to keep a high unit profit (i.e., taking profit maximization behavior) when the rival puts a lot of products into the market. Therefore, we will study the Evolutionarily Stable Strategy (ESS) of the retailers' marketing objectives (revenue maximization and profit maximization) for a given wholesale price and investigate the effects of the manufacturer's wholesale price on the marketing objectives and order quantities of her retailers. We will also study the optimal wholesale pricing of the manufacturer from an indirect evolutionary perspective.

Much of the supply chain management literature studied the strategic competition among firms by employing orthodox game theory (non-cooperative and cooperative game theory). However, orthodox game theory assumes that: (a) players are fully rational and can take an optimal action (sophisticated); (b) they have common knowledge of rationality; (c) they know the rules of game; (d) the preferences of players are given. But, in reality, these assumptions may not hold for the players. The preferences (marketing objectives) of players (retailers) may change over time. Evolutionary game theory is an effective tool for solving these problems because it can remedy the drawbacks of orthodox game theory. In addition, evolutionary game theory gives a better answer on the selection of multiple equilibria than orthodox game theory. Evolutionary game theory, combining the evolution theory of Darwin with game theory, has become a powerful integrated tool to analyze evolutionary processes/outcomes that are driven by individual selection pressures. ESS is a basic concept of evolutionary game theory, focusing on the macro characteristics of population(s) consisting of individuals from a statistic perspective (Maynard Smith and Price, 1973). An ESS can repel any (sufficiently small) mutant behavior once it prevails in the population, i.e., the population cannot be invaded by a small (relative to the number in the initial population) subpopulation of individuals using a different strategy. To computing ESS, we first give or compute the payoff (profit) bi-matrix of the matched individuals in the one-shot game (i.e., the game that is once played by the two matched individuals and is the benchmark game of evolutionary game, see Table 1 including the quantity competition); secondly, we seek for the fraction satisfying

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Table 1
Payoff bi-matrix of the one-shot game on marketing objective choice

I	II	
	P	*R*
P	$\pi^{PP}(s,w)$, $\pi^{PP}(s,w)$	$\pi^{PR}(s,w)$, $\pi^{RP}(s,w)$
R	$\pi^{RP}(s,w)$, $\pi^{PR}(s,w)$	$\pi^{RR}(s,w)$, $\pi^{RR}(s,w)$

condition (i) in the ESS definition based on the payoffs; finally, we need to further judge condition (ii) in the ESS definition if there is equality in condition (i). Much of the evolutionary economics literature investigated the evolution of the individuals' (firms') behavior by developing one/or two-population evolutionary game models, where the two matched players will imitate the behavior with higher profitability in their own populations, respectively.

The observability of the successful strategy can fundamentally change the evolutionary dynamics or the stability of a strategy (Ruebeck, 1999; Dekel et al., 2007). Much of the economics literature assumed that the observed result on the rival's strategy (preference) is right. However, a player may make a mistake when she observes the rival's preference. We will find that the error probability of the observed result on the rival's preference significantly affects the ESS of the retailers' marketing objectives.

We will develop an indirect evolutionary game model of a supply chain consisting of one manufacturer/supplier and many retailers to study the effects of the wholesale price on the retailers' marketing objectives (preferences) and investigate the optimal wholesale pricing of the monopoly manufacturer/supplier from an indirect evolutionary perspective. We explicitly model the observability of marketing objective, the error probability of the observed result on the rival's preference, the market scale and the bargaining power of retailer to analyze their effects on the equilibrium outcome. The results of this paper can be applied to the case where the retail firms' owners determine marketing objectives and the retail managers determine order quantities to maximize their marketing objectives, where the marketing objective is a strategy of every owner. However, the marketing objective is the retailer's preference owning inertia in our model.

The rest of this paper is organized as follows. Related literature is reviewed in Section 2, which is followed by the basic model in Section 3. Section 4 studies the effect of the wholesale price on the ESS of marketing objective, and analyzes the effects of the observability of marketing objective and the error probability on the ESS by using a numerical example. Section 5 analyzes the optimal wholesale pricing of the manufacturer and presents an algorithm for computing the optimal wholesale price. Section 6 carries out the sensitivity analysis of some parameters and gives some managerial insights. Section 7 summarizes the main results of this paper and discusses the directions for future research.

2. Literature review

This paper is closely related to marketing objective, evolution of the firm's behavior and wholesale pricing. Now, we review the literature on marketing objective. Marris (1963) put maximum growth rate of revenue subject to minimum profit constraint and suggested that the success of the firm's behavior depends on the environment. Williamson (1966) developed a model to derive the behavior differences from the objectives of maximizing profits, maximizing growth and maximizing (discounted) sales. He found that there is substantial empirical evidence favoring abandonment of the profit maximization assumption. Baumol (1967) postulated that certain firms take behavior of sales revenue maximization subject to a minimum profit restraint. Smith et al. (1975) found that the evidence for 49 (regulated) firms supports sales revenue maximization rather than profit maximization. Nelson and Winter (1982) assumed that the non-profit-maximizing firm behavior is primarily caused by bounded rationality. Dutta and Radner (1999) investigated the behavior of a risky firm that raises funds in a competitive capital market and found that a profit-maximizing firm would, almost surely, fail in a finite time. However, non-profit-maximizing behavior may access success. Katz (1991) showed that a manager's decision based partly on revenue could be more profitable for owners than that driven solely by profit. Barros (1995) developed a duopoly model in which each firm has an owner and a manager, and found that two owners would like to design a contract based on a linear combination of profit and sales revenue that induces their managers to deviate from profit maximization. Romero (2000) considered bi-criteria firm utility functions with two arguments: sales revenue and profit, and found that, when entrepreneurs follow the bi-criteria policy, the demand for labor is higher than that when they maximize profits. Kaneda and Matsui (2003) developed a Cournot oligopoly game model in which each firm maximizes the weighted average of profit and another factor such as revenue, market share, negative of cost, and profit per worker. In the models above, the preference and the weights of the profits are common knowledge for all firms. However, the preference may be imperfectly observable. What are the effects of the observability of preference? Ruebeck (1999) studied the imitation process of players who play the repeated prisoners' dilemma by developing two classes of evolutionary models, unobservable strategies and observable strategies. But he did not investigate the case with partially observable strategy. We will study the effect of the observability of preference (marketing objective) on the equilibrium outcome.

There are a few papers on behavior evolution related to this paper. Samuelson and Swinkels (2006) analyzed the effect of information on the evolutionary path and argued that human utility embodies a number of seemingly irrational aspects. Dekel et al. (2007) studied the evolution of preferences by employing evolutionary game theory. Shi et al. (2005) developed an evolutionary game model with service to study the pricing strategies of retailers and found that the everyday low pricing strategy may coexist with a high/low pricing strategy. Schaffer (1989) found that profit-maximizers are not necessarily the best survivors because of the possibility of 'spiteful' behavior if firms have market power. Rhode and Stegeman (2001) showed that the managers' mean objectives are distorted towards revenue maximization in the Cournot game if managerial incentives evolve through imitation. Xiao and Yu (2006b) developed a two-population model of two-vertically integrated channels with differentiated goods and found that revenue maximization might be an ESS and profit maximization strategy might be unstable in the quantity-setting situation. However, in the price-setting situation with linear demand functions, profit maximization is a unique ESS. Thus, we develop a quantity-setting model.

Game theory in supply chain management is becoming more and more pervasive, in particular, employing orthodox (non-cooperative and cooperative) game theory to study the decisions of the members of supply chain (Cachon and Netessine, 2004; Leng and Parlar, 2005). However, as what we have pointed out in Section 1, evolutionary game theory can overcome some limitations of orthodox game theory. Wholesale pricing is an important topic of supply chain management (Ingene and Parry, 2000; Chen et al., 2001; Qi et al., 2004). But, much of the supply chain management literature assumed that players are rational and did not consider the effect of the preference of player on the wholesale price. We will develop an indirect evolutionary model to investigate this effect. The indirect evolutionary approach does not deny rational decision-making. It assumes that players maximize the expected