



Prisoner's dilemma on behavioral choices in the presence of sticky prices: Farsightedness vs. myopia



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ABSTRACT

When making decisions in a dynamic environment, myopic supply chain members tend to ignore the future effects of their decisions on the evolution of state dynamics. By contrast, far-sighted decision-makers consider about the impacts of current decisions on both current profits and future profits. In order to study how behavioral choices affect the operation decisions and profits of supply chain members, we develop a differential game with sticky prices, where one manufacturer purchases components from one supplier and makes final products for end customers. The supplier decides on its wholesale price while the manufacturer sets its production quantity. Either of supply chain members has two behavioral choices: myopia and farsightedness. We derive and compare equilibrium solutions under four different behavioral combinations. Our analysis shows that there always exists a prisoner's dilemma caused by behavioral choices: farsightedness is a dominant strategy for either the supplier or the manufacturer, but both to act myopically makes both of them better off. Furthermore, comparing with other scenarios, the whole supply chain obtains the highest profit when both players are myopic. In addition, we introduce a revenue sharing contract with static wholesale price to mitigate the adverse impacts of the prisoner's dilemma.

1. Introduction

Today, the diversification of customer demand drives the market into differentiated segments. To survive and boost in a certain segment, a firm needs to make a series of decisions related to its main business in order to gain enough profits during its operation periods. When making decisions over operation periods, different firms have different focuses. Specifically, myopic firms only focus on their short-term performance, while far-sighted firms are more thoughtful and prospective and consider about the impacts of current decisions not only on current profits but also on future profits. However, confronted with the complex and changing market, it is very difficult to be far-sighted for decision makers. There are many obstacles to overcome, such as information shortage or high cost. That is why some firms have to give up exploring the impacts of current decisions on future profits. Even with accessible information, some firms still prefer myopic strategy with full consideration of their development. Therefore, which strategy is better off: to be far-sighted or to be myopic? Motivated by this question, our paper adopts quantitative method to figure out an answer for decision makers and our analysis offers some managerial insights for references.

As one of key factors in decision-making process, the evolution of

product price conveys critical information. If a firm has better information about product price, it can exploit that as its advantage. However, even if members in a supply chain have similar information base, their profits may differ due to different strategic commitments, such as the choice between farsightedness and myopia. To simplify decision problems, a large body of operations management literature assumes price has a linear correlation with operation decisions such as supply quantity and these operation decisions result in immediate effects on the price. However, in practice, it takes time for the price to react to the decisions. In other words, the price shows its stickiness during evolution. Based on this fact, price stickiness is modeled by the change rate of price. In our paper, this change rate is proportional to the gap between current price and the price indicated by linear demand function with certain production quantity (e.g., [Fershtman and Kamien \(1987\)](#), [Dockner and Löffler \(2015\)](#)). This consideration on sticky prices makes decision problems more realistic but more complicated. Under such a dynamic environment, far-sighted players consider about the effects of current decisions on the dynamics of price while these myopic ones ignore the corresponding effects and only focus on short-term profits. On this basis, our main objective is to investigate the impacts of behavioral choices on the operation decisions and profits of supply chain members in the presence of sticky prices. To be specific,

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we aim to answer the following questions:

- (i) Equilibrium solutions: How do supply chain members make their operation decisions under different behavioral combinations?
- (ii) Strategy comparison: How do the supply chain members' decisions change across different behavioral combinations?
- (iii) Behavioral preference: Which scenario is the most beneficial one for a certain member? If to be far-sighted or to be myopic is endogenous, does there exist an equilibrium for the behavioral choices of supply chain members?

To this end, we establish a differential game in a bilateral monopoly supply chain composed of one supplier and one manufacturer. The manufacturer purchases components from the supplier and produces final products for end customers. They play a Stackelberg game with the supplier as the leader deciding on its wholesale price and the manufacturer as the follower setting its production quantity. As either of supply chain members faces two choices, i.e., far-sighted strategy or myopic strategy, there are four different behavioral combinations. Under each scenario, we derive equilibrium production quantity and wholesale price. Comparing these solutions across scenarios, we obtain some interesting results with important managerial insights. There always exists a prisoner's dilemma on behavioral choices for both players. Farsightedness is the dominant strategy for either the supplier or the manufacturer; however, both to act myopically benefits either of them more than both to be far-sighted. In addition, comparing with other scenarios, the whole supply chain obtains the highest profit when both members are myopic. Moreover, we introduce a revenue sharing contract with static wholesale price to mitigate the adverse impacts of the prisoner's dilemma and improve supply chain performance.

The remainder of this paper is organized as follows. Section 2 reviews relevant literature. Section 3 develops a differential game involving the dynamics of sticky prices. Section 4 derives equilibrium solutions under four different behavioral combinations. Section 5 analyzes behavioral strategies and their impacts on profits. Section 6 introduces a revenue sharing contract to help avoid the prisoner's dilemma. Section 7 summarizes main conclusions and discusses our limitations and future research directions.

2. Literature review

Our study is related to multiple streams of researches. Among them, there are two topics most closely relevant with our paper: one is about sticky prices in differential games and the other is myopic behavior. In the following, we review existing literature and highlight our contributions.

One stream related to our research is about sticky prices under differential games. Studies on sticky prices can be dated back to [Simaan and Takayama \(1978\)](#) who focus on dynamic duopoly and consider a united price adjustment rate with capacity constraints. As one of their extensions, [Fershtman and Kamien \(1987\)](#) allow for an arbitrary adjustment rate and discuss instantaneous adjustment. Another extension of [Simaan and Takayama \(1978\)](#) belongs to [Tsutsui and Mino \(1990\)](#) who are the first to identify the analogy of nonlinear Markov feedback strategies. Their technique is applicable to a class of differential games which have one state variable and an infinite time horizon. On the basis of preceding researches, [Piga \(2000\)](#) makes a modification with advertisement enlarging market size. He discusses the linkages between output and advertising strategies under three different equilibria, namely open-loop equilibrium, linear feedback Markov equilibrium and nonlinear feedback Markov equilibrium. [Cellini and Lambertini \(2004\)](#) characterize open-loop, feedback, and closed-loop memoryless equilibria in a dynamic oligopoly model with sticky prices, and further investigate an industry with more than two players. [Cellini and Lambertini \(2007\)](#) turn to differentiated goods with sticky prices, which differs from homogeneous goods in previous discussion. They

analyze both open-loop equilibrium and closed-loop memoryless Nash equilibrium, and investigate the first-best allocation where a planner controls firms' output decisions to maximize social welfare. Using a dynamic oligopolistic industry model involving sticky prices, a recent study by [Dockner and Löffler \(2015\)](#) proves rivalry restraint as equilibrium behavior among firm owners who delegate decisions to managers. In general, the essential difference between these models and ours is that they focus on sticky prices under horizontal competition, while we study vertical competition and further investigate the effects of myopia on strategies and profits in the presence of sticky prices.

Another relevant stream is myopic behavior, which has become more and more popular recently. In existing literature, differential game models are widely used in exploring interactions between supply chain members. [He et al. \(2007\)](#) give a comprehensive review on differential game models. In their review, several studies involve myopia which refers to the behavior without consideration about the impacts of today's decision on tomorrow's outcome. In the terminology of optimization, firms who solve dynamic optimization problem as a series of static optimization problems are regarded as myopic decision-makers. Put that differently, the myopic firms do not consider the impacts of current actions on system states which in turn influence their performance index. On the topic of myopic behavior, there are many researches exploring from the aspect of supply or distribution channels. As our model is based on a bilateral monopoly supply chain, we focus on myopia under such a structure. [Jørgensen et al. \(2001\)](#) study the effects of strategic interactions on both pricing and advertising under the leadership of myopic retailer. [Taboubi and Zaccour \(2002\)](#) find the myopic retailer prices lower and invests less in promotion than the non-myopic retailer does. [Gutierrez and He \(2011\)](#) discuss inter-temporal channel coordination issues in a supply chain for innovative durable products where the demand is affected by word-of-mouth effects as well as retail price. They point out that the manufacturer does not always find it more profitable to cooperate with a far-sighted retailer, and sometimes it is better off to choose a myopic retailer. [Kogan and Tapiero \(2007\)](#) consider a bilateral monopoly supply chain similar with news-vendor problem which incorporates production control. Their results show that if the manufacturer is myopic, it orders less in the decentralized supply chain than in the centralized one. Different from the literature above, we study the impacts of myopic and far-sighted behaviors at both the supplier and the manufacturer levels, and pay more attention to behavior selection problems for both players involving sticky prices. Our results show that farsightedness is the dominant strategy for both players while either of them is better off when both choose myopia, which further leads to the prisoner's dilemma.

Except for these mentioned literature, there are three papers most similar to our study in examining the effects of behavioral choices on the profits of supply chain members. They are [Benchekroun et al. \(2009\)](#), [Martín-Herrán et al. \(2012\)](#), and [Benchekroun and Martín-Herrán \(2016\)](#). Our study differs from them in several aspects. The major difference between farsightedness and myopia is whether decision-makers account for the state dynamics or not. [Benchekroun et al. \(2009\)](#) and [Martín-Herrán et al. \(2012\)](#) distinguish far-sighted players from myopic ones with the dynamics of reference price, while the latter consider about the influences of quality on reference price. As for [Benchekroun and Martín-Herrán \(2016\)](#), they introduce the stock of pollution as state dynamics into far-sighted players' account. When it comes to our paper, we focus on the topic of sticky prices and provide both channel members with both behavioral options. However, according to [Benchekroun et al. \(2009\)](#), the manufacturers are able to choose behavioral modes while the retailer can only set static price; in contrast, the retailer chooses either of behavioral choices always with a far-sighted manufacturer in [Martín-Herrán et al. \(2012\)](#). [Benchekroun and Martín-Herrán \(2016\)](#) offer both behavioral choices to all players but not in vertical competition. As for the results,

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