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Price and Quality Competition: the Effect of Directly and Indirectly Selling Under Two Competitive Manufacturers and One Common Retailer

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***Abstract** – Nowadays, different important indicators besides price on product sales and durability of manufacturers on the market have been considered. This paper considers the demand, cost, competitive pricing behavior, substitutability, and quality in the proposed model under two competitive manufacturers and one standard retailer. Each competitive manufacturer can sell a product directly (D) or indirectly (I) to the customer. So, we develop three scenarios for delivering the manufacture's product to the end customer. In scenario DD, two manufacturers sell directly. However, in scenario II, they sell through the familiar retailer to the end customer (indirectly), and in scenario ID, one of the manufacturers sells directly, but the other sell indirectly. Finally, some numerical examples are given to illustrate the effectiveness of the proposed scenarios in the model. Numerical examples show that the total profit of scenario DD is less than the total profit of Scenario ID. When two manufacturers' products' substitution rate is close to one, each player's total profit in scenario II is greater than the other two scenarios.*

***Keywords**– Competitive pricing, product quality, game theory, dual-channel system, online selling.*

I. INTRODUCTION

The manufacturer needs to decide whether to sell its product directly or indirectly with the same quality and price through a channel. In the indirect mode, the manufacturer sells its product to a retailer (intermediary), and this retailer delivers the goods to the end customer, but in the direct mode, the manufacturer supplies the product to the end customer directly and online. When there is no competitor, we have a manufacturer and a retailer considering quality and pricing issues that investigate them (Chen et al., 2017). An extension of this study area is when another competitor manufacturer in the market is desirable.

Chen et al. (2017) considered dual-channel supply chains that contain a manufacturer and retailer. They investigated price and quality decisions through three channels: a retail channel, a direct channel, and a dual-channel with both retail and direct channels. In a direct channel, the manufacturer sells the product directly to the customer. Also, they considered the cooperative and non-cooperative between retailer and manufacturer in their study. Wang et al. (2017) considered a supply chain that contains two manufacturers that each one has a retailer. They investigated three scenarios; the manufacturers indirectly sell their product to the retailer in the first scenario. In the second scenario, they sell directly to the customer without retailers' cooperation, and in the third scenario, one of the manufacturers sells directly, and the other sells indirectly. Li and Chen (2018) developed a game-theoretical model to study the quality and

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price competition of two manufacturers' brands sold by a typical retailer. Differing from these studies, we consider the direct selling for manufacturers.

To the best of our knowledge, existing studies have not simultaneously considered two competitive manufacturers that sell their substitutability and quality- differentiated products through a retailer or selling online. In this paper, we address this gap and ask the following research questions. First, how does selling direct or indirect influence the competitive manufacturers? Second, how do competitive manufacturers prefer to distribute their quality-differentiated products through the direct or indirect channel when the products are substitutable? Finally, how do the profits of manufacturers and retailers are affected by the sensitivities of selling price and product quality?

In this paper, we study the problem of optimal pricing and quality designing in a supply chain with two competitive manufacturers and one retailer to answer the questions above. The demand, cost, competitive pricing behavior, and quality issues are considered in the proposed model. The price and quality of each manufacturer influence the demand function of the other manufacturer. This paper's main contribution is that we consider a retailer that acts as a mediator for both manufacturers, and the other is that we consider a demand function based on (Chen et al., 2017) to more compatibility with real-world applications. The rest of this paper is organized as follows: In Section 2, the relevant works are reviewed. In Section 3, the problem and three scenarios are described. The experimental results and numerical analysis are presented in Section 4. Finally, concluding remarks and future research ideas are provided in Section 5.

II. LITERATURE REVIEW

This paper is related to two streams of literature: one delves into joint pricing and quality decisions while the other discusses the effect of directly or indirectly selling in the supply chain. Hendershott & Zhang (2006) considered online selling in a dual-channel supply chain and determined its impacts on consumer surplus, social welfare, and search cost, but they did not consider the quality decision. In the online direct selling two-echelon supply chain, Li et al. (2013) examined the impact of the return policy, product quality, and pricing strategy on the customer's purchase and the return decisions. Abbey et al. (2015) researched the optimal pricing of the new and remanufactured products using a model of consumers' preferences based on extensive experimentation. Saha (2016) considers a manufacturer, distributor, and retailer supply chain where the manufacturer may enter a direct sales channel. He analysis the impact of different channel structures with and without coordination.

Yoo (2014) investigated the joint decision problem of the return policy and product quality decisions in a decentralized system under risk aversion. Chan Choi & Coughlan (2006) researched the retailer's problem of differentiating the brand in terms of product quality and product features. Matsubayashi (2007) studied price and quality competition in the internet market by considering two business strategies: Product differentiation and vertical integration.

Lin et al. (2001) present an algorithm for deriving the long-term quality level policies, price, and advertisement for a product. Balachandran & Radhakrishnan (2005) explored the quality implications of warranties in a buyer-supplier supply chain and examine how the warranty contract affects the supplier's quality choice. They found that the first-best quality is not always achieved in the double moral hazard case. Zhao et al. (2012) studied price competition in a supply chain with two competing retailers and one ordinary manufacturer under a centralized pricing model and three decentralized pricing models. They used a fuzzy variable for defining consumer demands and manufacturing costs.

Zhao et al. (2012) explored the roles of two competitive manufacturers and the typical retailer in a fuzzy supply chain under four different decision scenarios. Modak et al. (2015) considered a manufacturer–retailer supply chain under centralized and decentralized situations with the demand function depends on the product's quality, warranty, and sales price. Carlton & Dana (2008) investigated the effects of uncertainty on a manufacturer's jointly optimal pricing and quality decisions for different aggregate demand functions.

Liu et al. (2018) focused on optimal quality and quantity provisions for centralized and decentralized distribution. They investigated the effects of market size uncertainty on the problem. Wang & Li (2012) considered perishable food management in grocery retail chains and the impact of the quality control and excessive inventories, and timing and frequency of the discount in a selling period on retailing performance. Maiti & Giri (2015) studied a closed-loop supply chain considering the retail price and quality-dependent demand in a three-echelon supply chain containing suppliers, manufacturers, and retailers. Pal et al. (2016) consider a two-echelon competitive supply chain consisting of two rivaling retailers and one standard supplier with a trade credit policy. Giri et al. (2017) developed an optimal ordering, pricing, and quality management strategy where demand depends on price and product quality. Giri et al. (2017) considered the pricing and returned product collection decisions for a closed-loop supply chain with two dual channels. Chung and Lee (2017) investigate a supply chain that includes one retailer and one or two manufacturers. The manufacturer sells national brands through the retailer. They study the store brand quality and retailer's product line design decisions. Cui (2019) considers a supply chain consisting of an original equipment manufacturer (OEM) as the quality leader and a contract manufacturer (CM) as a free rider for the OEM's quality investment. The result shows a threshold for the CM's imitating capability to encroach when the OEM's quality investment is possible. Zhang et al. (2019) consider a supply chain with one manufacturer and one retailer. They investigate encroachment strategy with the quality decision under asymmetric information. The result shows that encroachment may lead to a lower quality.

Jabarzare and Rasti-Barzoki (2020)' study a supply chain including one manufacturer and one packaging company. They use a game-theoretic approach for pricing and determining quality levels through coordination contracts. Table I summarizes the reviewed literature on the pricing, competition, and quality decisions in the supply chain.

According to the literature mentioned above, we know that the product's price and quality are significant for the customers and their utility function. Manufacturers and retailers in today's competitive market are trying to keep and also increase their market share. Therefore, our paper's contribution is modeling a network with two competitive manufacturers and one standard retailer supply chain that the price and quality competitive have the primary role in it. We also investigate directly and indirectly selling for two competitive manufacturers.

Table I. Compares this study with studies that are closely related to the current paper

Author(s)	*The number of players*		*Channel*		*competition*	*Quality decision*
	Retailer	*Manufacturer*	*Direct*	*Indirect*		
Chung and Lee (2017)	1	2		✓	✓	✓
Li and Chen (2018)	1	1		✓	✓	
Cui (2019)		2	✓		✓	✓
Zhang, Li, Zhang, and Dai (2019)	1	1	✓	✓	✓	✓
Jabarzare and Rasti-Barzoki (2020)	1	1		✓		✓
Wang et al. (2017)	2	2	✓	✓	✓	
Chen et al. (2017)	1	1	✓	✓		✓
Current study	1	2	✓	✓	✓	✓

III. PROBLEM DESCRIPTION

We consider a two-echelon supply chain problem, including two competitive manufacturers and one familiar retailer. Each manufacturer determines its quality and price to the customer or wholesale price to the retailer due to maximizing their profits and setting the selling price to earn high profit.

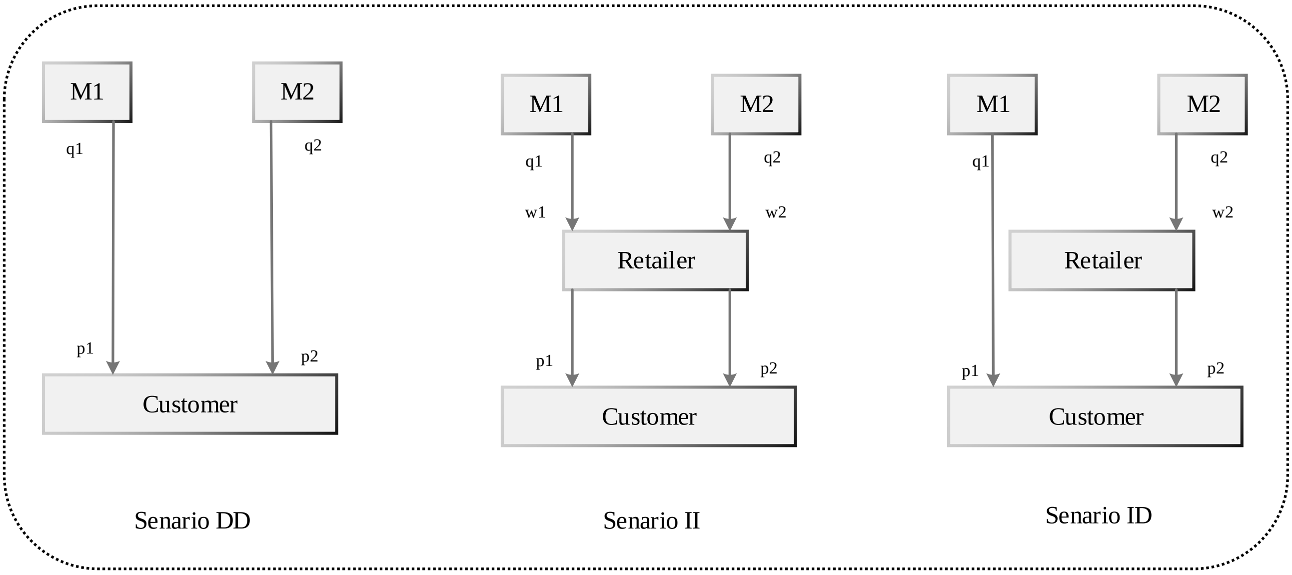


Fig. 1. The frames of studied supply chain

Manufacturers produce their products and sell them to the customer, directly or indirectly (with the retailer). If they sell products to the retailer and then the retailer sells them to the customer, we called it indirectly (I), and if the manufacturers sell their product without the retailer's cooperation, we called it directly (D).

We consider three scenarios shown in Fig. (1) to consider all possible situations between two manufacturers and retailers. As shown in scenario DD, the manufacturers sell their products directly to the customer, and retailers have no roll scenario DD, but in scenario II, the manufacturers sell their products to a common retailer and then sell to the end customer. In the third scenario (ID), one of the manufacturers (M1) sells directly, and the other one (M2) sells indirectly to the customer.

The following notations are used in the paper to formulate the studied problem.

Indices

i	The index of products	i=1, 2
m	The index of manufacturers	m=1, 2
r	Denote the retailer	

Parameters

A	Positive constant
θ	Denote the substitutability of product
y	$y \geq 0$ is the coefficient of the effect of an increase in the product quality of each manufacturer's demand
D_i	Demand for product i
Π_R	The retailer's profit ($)

Π_{Mm} The m[th] manufacturers' profit ($)

Decision variables

H_i Level of quality that manufacturer uses in its product i

p_i Price of product i ($)

w_i Manufacturer's wholesale price of the product i that sells to retailers ($)

Eq. (1) shows the utility function that it is a developed case that (Chen et al., 2017) use for their paper.

$$U = A_1q_1 + A_2q_2 - \frac{1}{2}(q_1^2+q_2^2) - \theta q_1q_2 + \sqrt{y}H_1q_1 + \sqrt{y}H_2q_2 - p_1q_1 - p_2q_2 \quad (1)$$

For simplification, we consider that $A = A_1 = A_2$

The customer selects the optimal quantities of products to maximize her utility. So we have that $\frac{\partial U}{\partial q_1} = 0$ and $\frac{\partial U}{\partial q_2} = 0$, can obtain the following demand (Eqs. (2,3)) function for each product

$$D_1 = \frac{A - \theta \mathrm{A} + \sqrt{y}H_1 - \sqrt{y}\theta H_2 - p_1 + \theta p_2}{1-\theta^2} \quad (2)$$

$$D_2 = \frac{A - \theta \mathrm{A} - \sqrt{y}\theta H_1 + \sqrt{y}H_2 + \theta p_1 - p_2}{1-\theta^2} \quad (3)$$

Equations 2 and 3 show the demand function for manufacturers 1 and 2 (M1 and M2). With the above demand function, we model our scenarios that in the following discussion about them.

These scenarios are described in more detail throughout the next three sections, and the required equations are presented.

A. Scenario DD: the manufacturers sell directly to the end customer

In this scenario, we consider that the manufacturers sell their products directly to the end customer, and so the Equations (4,5) show the profit function for each manufacturer.

$$\max \Pi_{M1} = (p_1 - \xi H_1)D_1 - \frac{kH_1^2}{2} \quad (4)$$

$$\max \Pi_{M2} = (p_2 - \xi H_2)D_2 - \frac{kH_2^2}{2} \quad (5)$$

For finding the Equilibrium, two steps must proceed. In the First step, derivatives of each manufacture' profit function with decision variables H_1 and H_2, respectively shown in $\frac{\partial \Pi_{M1}}{\partial H1} = 0$ and $\frac{\partial \Pi_{M2}}{\partial H2} = 0$ and achieve the H_1 and H_2, in the second step by replacing these variables in Equations (4) and (5) and solve the $\frac{\partial \Pi_{M1}}{\partial p1} = 0$ and $\frac{\partial \Pi_{M2}}{\partial p2} = 0$ providing the optimal values for decision variables. The four variables H_1, H_2, p_1, and p_2 can be calculated, as shown in Table II. Then the values of the manufacturer's profit can be calculated.

Table II. The results of scenario DD

Variable	*Outcome*
p_1	$\frac{A(-1+\theta^2-\sqrt{y}\xi+\xi^2)}{-2+y-\theta+\theta^2-2\sqrt{y}\xi+\xi^2}$
p_2	$\frac{A(-1+\theta^2-\sqrt{y}\xi+\xi^2)}{-2+y-\theta+\theta^2-2\sqrt{y}\xi+\xi^2}$
H_1	$\frac{A(\xi-\sqrt{y})}{-2+y-\theta+\theta^2-2\sqrt{y}\xi+\xi^2}$
H_2	$\frac{A(\xi-\sqrt{y})}{-2+y-\theta+\theta^2-2\sqrt{y}\xi+\xi^2}$
Π_{M1}	$\frac{A^2(-1+\theta^2)}{((-2+\theta)(1+\theta)+(\sqrt{y}-\xi)^2)^2}$
Π_{M2}	$\frac{A^2(-1+\theta^2)}{((-2+\theta)(1+\theta)+(\sqrt{y}-\xi)^2)^2}$

B. Scenario II: the manufacturers sell indirectly to end customer

In the previous section, we considered a situation that the products sold directly to the end customer, while in scenario II, the manufacturers sell their product to the retailer and then sell the customer.

We use the Stackelberg game theory that manufacturers play the lead role and the retailer follows them. As mentioned above, we can write the profit function as Equations (6)-(8). At the first step, the manufacturer sets their price and quality, and then the retailer determines the selling price.

$$\max \Pi_{M1} = (w_1 - \xi H_1)D_1 - \frac{kH_1^2}{2} \tag{6}$$

$$\max \Pi_{M2} = (w_2 - \xi H_2)D_2 - \frac{kH_2^2}{2} \tag{7}$$

$$\max \Pi_R = (p_1 - w_1)D_1 + (p_2 - w_2)D_2 \tag{8}$$

In this scenario, the first derivatives of the retailer's profit function with decision variables p_1 and p_2, respectively shown in $\frac{\partial \Pi_R}{\partial p1} = 0$ and $\frac{\partial \Pi_R}{\partial p2} = 0$ and achieve the p_1 and $p_{2,}$ in the next, by replacing these variables in Equations (6) and (7) and solve the $\frac{\partial \Pi_{M1}}{\partial H1} = 0$ and $\frac{\partial \Pi_{M2}}{\partial H2} = 0$ providing the optimal values for decision variables. Results for each variable are shown in Table III.

Table III. The results of scenario II

Variable	*Outcome*
w_1	$-\frac{2A-2A\theta^2+A\sqrt{y}\xi-A\xi^2}{-4+y-2\theta+2\theta^2-2\sqrt{y}\xi+\xi^2}$
w_2	$-\frac{2A-2A\theta^2+A\sqrt{y}\xi-A\xi^2}{-4+y-2\theta+2\theta^2-2\sqrt{y}\xi+\xi^2}$
p_1	$A+\frac{A(1-y+\theta+\sqrt{y}\xi)}{2(-2+\theta)(1+\theta)+(\sqrt{y}-\xi)^2}$
p_2	$A+\frac{A(1-y+\theta+\sqrt{y}\xi)}{2(-2+\theta)(1+\theta)+(\sqrt{y}-\xi)^2}$
H_1	$-\frac{A(\sqrt{y}-\xi)}{-4+y-2\theta+2\theta^2-2\sqrt{y}\xi+\xi^2}$
H_2	$-\frac{A(\sqrt{y}-\xi)}{-4+y-2\theta+2\theta^2-2\sqrt{y}\xi+\xi^2}$
Π_{M1}	$\frac{A^2(2.-0.5y-2.\theta^2+1.\sqrt{y}\xi-0.5\xi^2)}{(-4.+y+\theta(-2.+2.\theta)-2.\sqrt{y}\xi+\xi^2)^2}$
Π_{M2}	$\frac{A^2(2.-0.5y-2.\theta^2+1.\sqrt{y}\xi-0.5\xi^2)}{(-4.+y+\theta(-2.+2.\theta)-2.\sqrt{y}\xi+\xi^2)^2}$
Π_R	$\frac{2A^2(1+\theta)}{(2(-2+\theta)(1+\theta)+(\sqrt{y}-\xi)^2)^2}$

C. Scenario DI: one of the manufacturers sells directly, and the other sells to the retailer

In this scenario, one of the manufacturers sells the products directly to the final customer, and the other manufacturer sells them to the retailer, and then the retailer delivers them to the final customer. As shown in Fig. (1), manufacturer 1 with price $p_1$and quality q_1 sells the customer and manufacturer 2 sells to the retailer with a wholesale price w_2 and quality q_2 and then he sells it to the end customer with p_2.

As mentioned above, the objective functions can formulate as Equations (9)-(11).

$$\max \Pi_{M1} = (p_1 - \xi H_1)D_1 - \frac{kH_1^2}{2} \tag{9}$$

$$\max \Pi_{M2} = (w_2 - \xi H_2)D_2 - \frac{kH_2^2}{2} \tag{10}$$

$$\max \Pi_R = (p_2 - w_2)D_2 \tag{11}$$

In scenario DI, the first derivatives of retailer's profit function with decision variables p_1 and p_2, respectively shown in $\frac{\partial \Pi_{M2}}{\partial p1} = 0$ and $\frac{\partial \Pi_R}{\partial p2} = 0$ and achieve the p_1 and p_2, in the next, by replacing these variables in Equations (9) and (10) and solve the $\frac{\partial \Pi_{M1}}{\partial H1} = 0$ and $\frac{\partial \Pi_{M2}}{\partial H2} = 0$ providing the optimal values for decision variables. Results for each variable are shown in Table IV.

Table IV. The results of scenario DI

variable	*Outcome*
w_2	$\frac{A(4-5\theta^2+\theta^4-\sqrt{y}(-2+\theta^2)\xi+(-2+\theta^2)\xi^2)((-2+\theta)(-1+\theta)(2+\theta)^2+2y(-2+\theta^2)-4\sqrt{y}(-2+\theta^2)\xi+2(-2+\theta^2)\xi^2)}{\left(\begin{array}{c}(-2+\theta^2)(2y^2(-2+\theta^2)+2(-4+\theta^2)^2(-1+\theta^2)-8y^{3/2}(-2+\theta^2)\xi+(24-24\theta^2+5\theta^4)\xi^2\\+2(-2+\theta^2)\xi^4+y(24-24\theta^2+5\theta^4+12(-2+\theta^2)\xi^2)-2\sqrt{y}\xi(5\theta^4+4\theta^2(-6+\xi^2)-8(-3+\xi^2)))\end{array}\right)}$
p_1	$\frac{A(4-5\theta^2+\theta^4-2\sqrt{y}(-2+\theta^2)\xi+2(-2+\theta^2)\xi^2)(8+y(-2+\theta^2)-2\sqrt{y}(-2+\theta^2)\xi-2\xi^2+\theta(-2+\theta(-9+\theta+2\theta^2+\xi^2)))}{\left(\begin{array}{c}(-2+\theta^2)(2y^2(-2+\theta^2)+2(-4+\theta^2)^2(-1+\theta^2)-8y^{3/2}(-2+\theta^2)\xi+(24-24\theta^2+5\theta^4)\xi^2\\+2(-2+\theta^2)\xi^4+y(24-24\theta^2+5\theta^4+12(-2+\theta^2)\xi^2)-2\sqrt{y}\xi(5\theta^4+4\theta^2(-6+\xi^2)-8(-3+\xi^2)))\end{array}\right)}$
p_2	$\frac{A(4-5\theta^2+\theta^4-2\sqrt{y}(-2+\theta^2)\xi+2(-2+\theta^2)\xi^2)(8+y(-2+\theta^2)-2\sqrt{y}(-2+\theta^2)\xi-2\xi^2+\theta(-2+\theta(-9+\theta+2\theta^2+\xi^2)))}{\left(\begin{array}{c}(-2+\theta^2)(2y^2(-2+\theta^2)+2(-4+\theta^2)^2(-1+\theta^2)-8y^{3/2}(-2+\theta^2)\xi+(24-24\theta^2+5\theta^4)\xi^2\\+2(-2+\theta^2)\xi^4+y(24-24\theta^2+5\theta^4+12(-2+\theta^2)\xi^2)-2\sqrt{y}\xi(5\theta^4+4\theta^2(-6+\xi^2)-8(-3+\xi^2)))\end{array}\right)}$
H_1	$-\frac{2A(\sqrt{y}-\xi)(8+y(-2+\theta^2)-2\sqrt{y}(-2+\theta^2)\xi-2\xi^2+\theta(-2+\theta(-9+\theta+2\theta^2+\xi^2)))}{\left(\begin{array}{c}2y^2(-2+\theta^2)+2(-4+\theta^2)^2(-1+\theta^2)-8y^{3/2}(-2+\theta^2)\xi+(24-24\theta^2+5\theta^4)\xi^2\\+2(-2+\theta^2)\xi^4+y(24-24\theta^2+5\theta^4+12(-2+\theta^2)\xi^2)-2\sqrt{y}\xi(5\theta^4+4\theta^2(-6+\xi^2)-8(-3+\xi^2))\end{array}\right)}$
H_2	$\frac{A}{-\sqrt{y}+\xi+\frac{2(-2+\theta)(1+\theta)}{-\sqrt{y}+\xi}-\frac{\theta(-4+\theta(-2+3\theta))(\sqrt{y}-\xi)}{(-2+\theta)(-1+\theta)(2+\theta)^2+2y(-2+\theta^2)-4\sqrt{y}(-2+\theta^2)\xi+2(-2+\theta^2)\xi^2}}$
Π_{M1}	$\frac{\Big(\begin{array}{c}(A^2(8+y(-2+\theta^2)-2\sqrt{y}(-2+\theta^2)\xi-2\xi^2+\theta(-2+\theta(-9+\theta+2\theta^2+\xi^2)))(2y^2(-2+\theta^2)^3+(-2+\theta)^2(-1+\theta)^2(1+\theta)(2+\theta)^3(-4+\theta+\theta^2)-8y^{3/2}(-2+\theta^2)\\+(-1+\theta)(2+\theta)(-3+2\theta)(-2+\theta^2)(-8+\theta(2+\theta)(-4+3\theta))\xi^2+2(-2+\theta^2)^3\xi^4\\+\sqrt{y}(-2+\theta^2)^2\xi(16(-3+\xi^2)+\theta(24+\theta(52+(-5+\theta)\theta(4+3\theta)-8\xi^2)))-y(-2+\theta^2)(-48(-1+\xi^2)+\theta(-40+(-2+\theta)\theta(38-11\theta-23\theta^2+\theta^3+3\theta^4-12(2+\theta)\end{array}}{(2-\theta^2)^2\left(\begin{array}{c}(2y^2(-2+\theta^2)+2(-4+\theta^2)^2(-1+\theta^2)-8y^{3/2}(-2+\theta^2)\xi+(24-24\theta^2+5\theta^4)\xi^2\\+2(-2+\theta^2)\xi^4+y(24-24\theta^2+5\theta^4+12(-2+\theta^2)\xi^2)-2\sqrt{y}\xi(5\theta^4+4\theta^2(-6+\xi^2)-8(-3+\xi^2)))\end{array}\right)^2}$
Π_{M2}	$\frac{\Big(\begin{array}{c}A^2(-1+\theta)(2+\theta)((-2+\theta)(1+\theta)(2y+2\theta-(3+y)\theta^2+\theta^4)-\sqrt{y}\theta^2(-2+\theta^2)\xi+(-2+\theta^2)(-2+\theta(-1+2\theta))\xi^2)\\((1+\theta)((-2+\theta)(-1+\theta)(2+\theta)^2(-4+\theta+\theta^2)+y(24-22\theta^2+5\theta^4))-\sqrt{y}(-2+\theta^2)(-16+\theta(2+\theta)(-8+7\theta))\xi+(-2+\theta^2)(-4+\theta(-4+\end{array}}{(1+\theta)(2-\theta^2)^2\left(\begin{array}{c}(2y^2(-2+\theta^2)+2(-4+\theta^2)^2(-1+\theta^2)-8y^{3/2}(-2+\theta^2)\xi+(24-24\theta^2+5\theta^4)\xi^2+\\2(-2+\theta^2)\xi^4+y(24-24\theta^2+5\theta^4+12(-2+\theta^2)\xi^2)-2\sqrt{y}\xi(5\theta^4+4\theta^2(-6+\xi^2)-8(-3+\xi^2))\end{array}\right)^2}$
Π_R	$\frac{\Big(\begin{array}{c}A^2(-1+\theta)(2+\theta)((2-\theta)(1+\theta)(2y+2\theta-(3+y)\theta^2+\theta^4)+\sqrt{y}\theta^2(-2+\theta^2)\xi+(-2+\theta^2)(-4+\theta(-4+\theta+2\theta^2))\xi^2))\\-(-2+\theta^2)(-2+\theta(-1+2\theta))\xi^2)((1+\theta)((-2+\theta)(-1+\theta)(2+\theta)^2(-4+\theta+\theta^2)+y(24-22\theta^2+5\theta^4))-\sqrt{y}(-2+\theta^2)(-16+\theta(2+\theta)(-8\end{array}}{\left(\begin{array}{c}((1+\theta)(-2+\theta^2)^2(2y^2(-2+\theta^2)+2(-4+\theta^2)^2(-1+\theta^2)-8y^{3/2}(-2+\theta^2)\xi+(24-24\theta^2+5\theta^4)\xi^2\\+2(-2+\theta^2)\xi^4+y(24-24\theta^2+5\theta^4+12(-2+\theta^2)\xi^2)-2\sqrt{y}\xi(5\theta^4+4\theta^2(-6+\xi^2)-8(-3+\xi^2)))2\end{array}\right)}$

IV. Numerical analysis

In this section, some numerical examples are used to analyze and evaluate the proposed two-level supply chain model and the effect of variables on each scenario between the supply chain members. We assume $A = 5$, $\xi = 0.5$, $\theta = 0.4$, $y = 0.5$.

Each manufacturer sells the selling price and quality level of products in all scenarios plays a vital role in choosing the optimal strategy. Hence, the sensitivity of this variable will be examined further. All the data and computer program code (written by Wolfram Mathematica 11) are available upon request from the authors.

A. Symmetric scenarios

In this section, we examine the sensitivity of the symmetric scenarios' parameters (Scenario II and DD). As with the study of models, it is clear that in these two scenarios, manufacturers' behavior is symmetrical and is similar to each other, so the behavior of variables and profit functions in both of these scenarios will be examined. Table V illustrates the sensitivity of each player's variables and profits and their demand compared to the main parameters of the problem. In the following, we will examine the impact of each of these parameters on the model. Of course, as detailed in the model section, in this scenario, two competitive manufacturers of their products are delivered directly and immediately to the customer.

Table V. The effect of parameter on system profits and variables in scenario DD

		p_1/p_2	H_1/H_2	D_1/D_2	Π_{M1}/Π_{M2}
ξ	0.60	2.0288	0.24031	2.2436	4.1996
	0.55	2.0909	0.35459	2.2570	4.2162
	0.50	2.0288	0.47132	2.2757	4.2392
	0.45	2.1981	0.59135	2.3000	4.2688
	0.40	2.2437	0.71564	2.3303	4.3052
θ	0.50	1.9336	0.46918	2.2654	3.7390
	0.45	2.0436	0.46971	2.268	3.9918
	0.40	2.1473	0.47132	2.2757	4.2392
	0.35	2.2454	0.47401	2.2887	4.4843
	0.30	2.3385	0.47784	2.3072	4.7300
y	0.60	2.2575	0.63429	2.3099	4.2808
	0.55	2.2021	0.55376	2.2919	4.2589
	0.50	2.1473	0.47132	2.2757	4.2392
	0.45	2.0929	0.38633	2.2616	4.2219
	0.40	2.0388	0.29799	2.2498	4.2072

According to Table V, the increase of parameters θ and ξ will reduce the products' sales price, the quality level of the products, the demand, and each manufacturer's profit. However, changes in the value of *y* reflect the two preceding parameters' behavior and increase all the variables and the manufacturer's profit.

Table VI shows the sensitivity of the variables to the problem parameters in scenario II. This scenario has two manufacturers, each selling its product through a retailer to the final customer. As shown in Table VI, the behavior of variables in scenario II is the same as we observed in scenario DD. With increasing parameters θ and ξ, all the problem variables are reduced, but with increasing *y*, this behavior's reverse is visible.

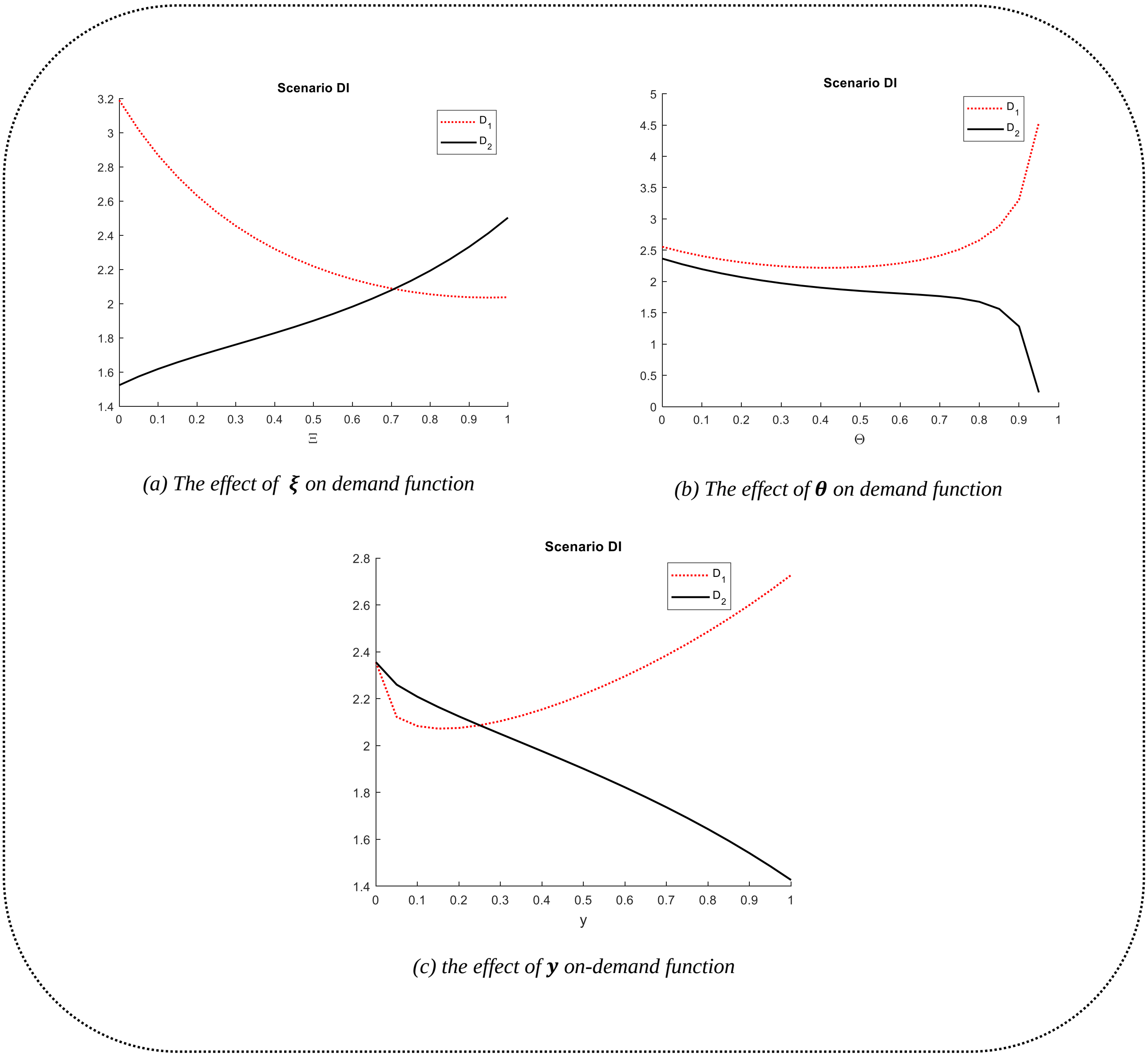
Table VI: The effect of parameter on system profits and variables in scenario II

		w_1/w_2	p_1/p_2	H_1/H_2	D_1/D_2	Π_{M1}/Π_{M2}	Π_R
ξ	0.60	0.11985	3.5182	0.1199	1.1189	2.0962	3.5057
	0.55	0.17631	3.5535	0.1763	1.1223	2.1003	3.5265
	0.50	0.23338	3.5874	0.2334	1.1269	2.1061	3.5555
	0.45	0.29125	3.6200	0.2913	1.1328	2.1134	3.593
	0.40	0.35012	3.6515	0.3501	1.1401	2.1223	3.6393
θ	0.50	0.23233	3.4816	0.2323	1.1218	1.8607	3.7753
	0.45	0.23259	3.536	0.2326	1.1231	1.9847	3.6577
	0.40	0.23338	3.5874	0.2334	1.1269	2.1061	3.5555
	0.35	0.2347	3.6361	0.2347	1.1332	2.2263	3.4675
	0.30	0.23658	3.6823	0.2366	1.1423	2.3469	3.3927
y	0.60	0.31172	3.6522	0.3117	1.1352	2.1163	3.6082
	0.55	0.27323	3.6195	0.2732	1.1308	2.1109	3.5804
	0.50	0.23338	3.5874	0.2334	1.1269	2.1061	3.5555
	0.45	0.1919	3.5560	0.1919	1.1234	2.1018	3.5336
	0.40	0.14841	3.5252	0.1484	1.1205	2.0981	3.5152

B. Asymmetric scenario

In this section, we review and analyze scenario ID. In this scenario, one manufacturer (manufacturer 1) offers its product directly to the end customer, and another manufacturer (manufacturers 2) delivers its product through a familiar retailer to the end customer.

Fig. (2) shows the sensitivity of demand for two competitive manufacturers relative to the problem parameters in scenario DI. It can be almost said that by increasing the parameters ξ, θ, and y, both products' demand behavior is opposite to each other. In Figures (2.b) and (2.c), increasing θ and y the demand for product 2, in which the manufacturer sells his product directly, shows a downward trend. In Fig. (2.b), when θ close to one and product more substitutability, manufacturer 1, which sells directly, almost gains all market. We can conclude in scenario DI when θ is close to one, the indirect manufacturer and retailer have a less chance to succeed in the market. Fig. (3) demonstrates the effect of parameters on the sale price and quality variables of scenario DI. In this figure, each product's price is equal (p_1=p_2), and the retail price has a similar procedure with them. The sensitivity of the price and quality variables for each product in parameters ξ and y behave contrary to each other, with the increase being ξ, this trend is decreasing. Noteworthy is the lack of sensitivity of the product's quality with the θ change, but as shown in Fig. (3.b), with the increase of θ, the price of manufacturers and retailers are falling.



(a) The effect of $\boldsymbol{\xi}$ *on demand function*

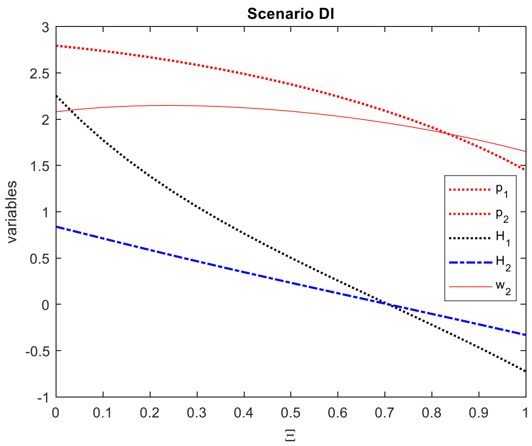
(b) The effect of $\boldsymbol{\theta}$ *on demand function*

(c) the effect of $\boldsymbol{y}$ *on-demand function*

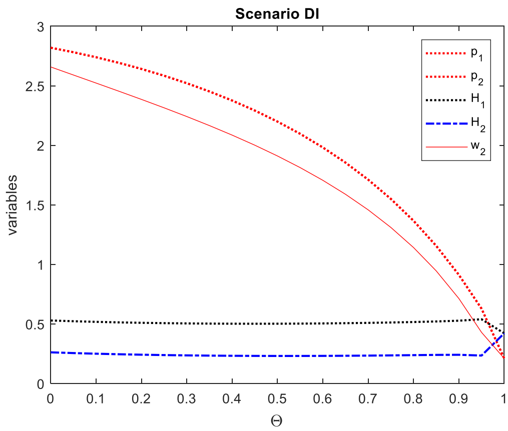
Fig. 2. The effect of parameters ξ, $\boldsymbol{\theta}$, **and y on-demand function in scenario DI**

Fig. (4) depicts the sensitivity of each players' profit in Scenario ID according to the model parameters. In Fig. (4), by increasing *y*, the retailer's profit and manufacturer 1 increase but the profit of manufacturer 2 decreases, which is precisely the inverse of this behavior can be seen in increasing the parameter ξ. In Fig. (4.b), it can be seen with the increase of the θ, the profitability of both manufacturers is reduced, but the retailer's profit against is indifferent to changes in this parameter. As shown in Fig. (2.b), by increasing the θ, the manufacturers try to decrease their selling price. As shown in Fig. (4.b), their profits decrease.

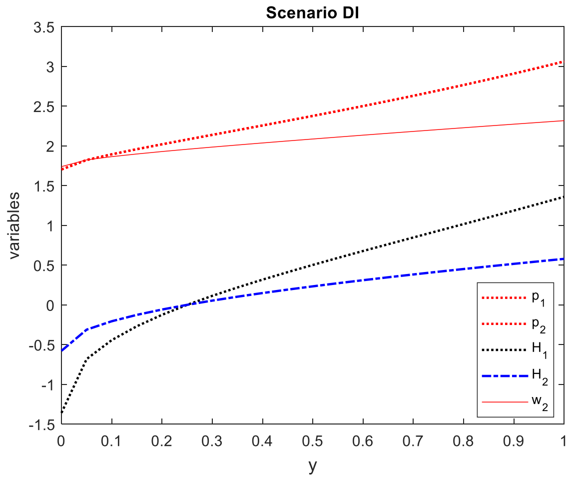
In Fig. (3.b), when θ=1, we have full substitutability, each has the same quality, level, and the selling price is equal to the full sale price, but in Fig. (4.b), easily seen that for θ=1 the profits of manufacturers and retailer are zero. As shown in Fig. (3.b), the profit of direct manufacture is more than indirect manufacture.



(a) The effect of ξ on variables



(b) The effect of θ on variables



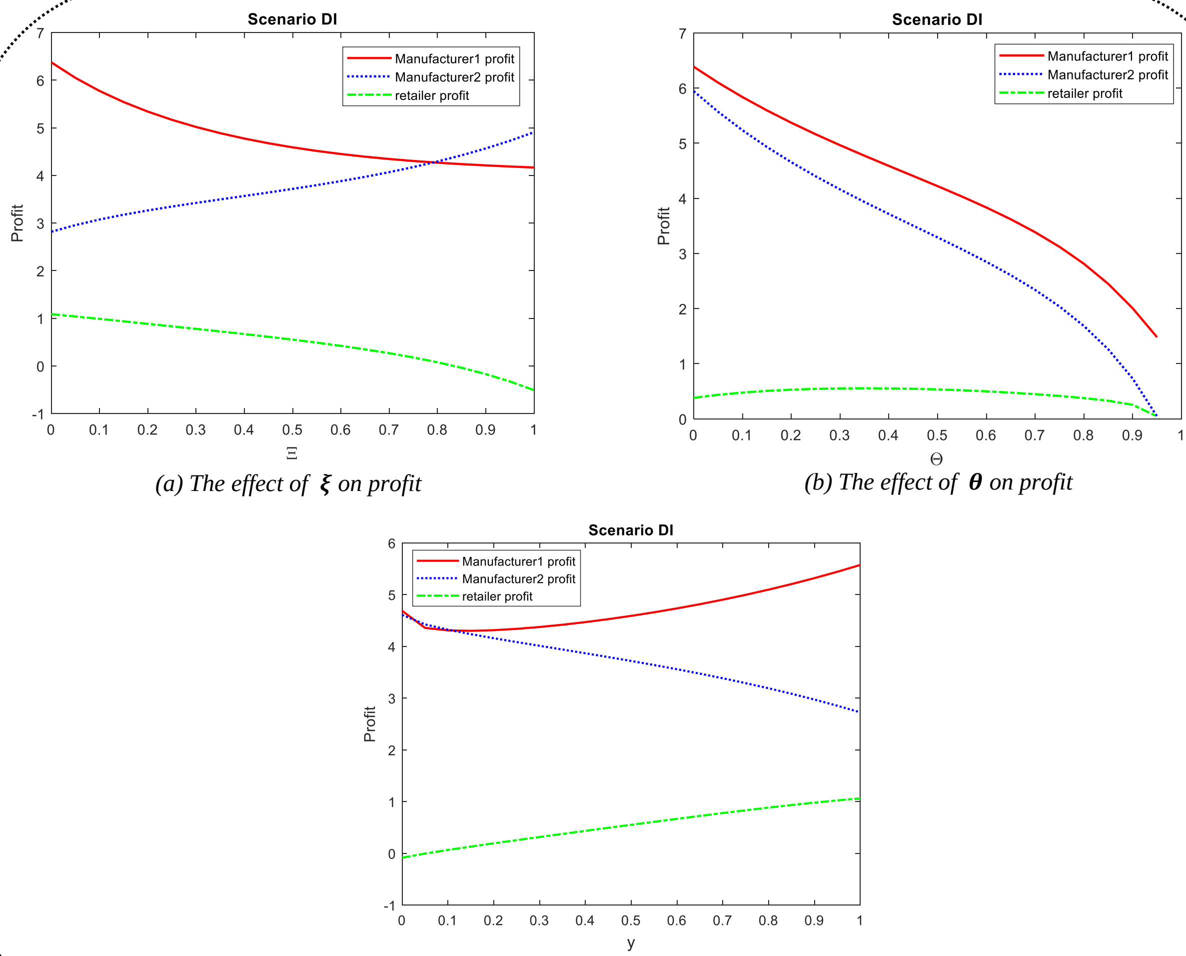
(c) The effect of y on variables

Fig. 3. The effect of parameters ξ, θ, and y on the variables in scenario DI

C. Different of scenarios

Here is a comparison between scenarios. We examine the overall supply chain profit for each scenario. In other words, we analyze the total profit of two manufacturers and a retailer in each scenario and the sensitivity of the scenario's profit to the problem's parameters.

Fig. 5 shows the total profit of scenario DD, DI, and II and the effect of parameters ξ, θ, and y, on them. As shown in Fig. 5, under the same conditions, the scenario's total profit is DI greater than the scenario's profit DD. In other words, a player like a retailer has not only not reduced the chain's profit, which has also boosted it. It is easy to see in Fig. 5(a,c) that scenario II has the lowest total profit than the other two scenarios.



(a) The effect of $\boldsymbol{\xi}$ *on profit*

(b) The effect of $\boldsymbol{\theta}$ *on profit*

(c) The effect of $\boldsymbol{y}$ *on profit*

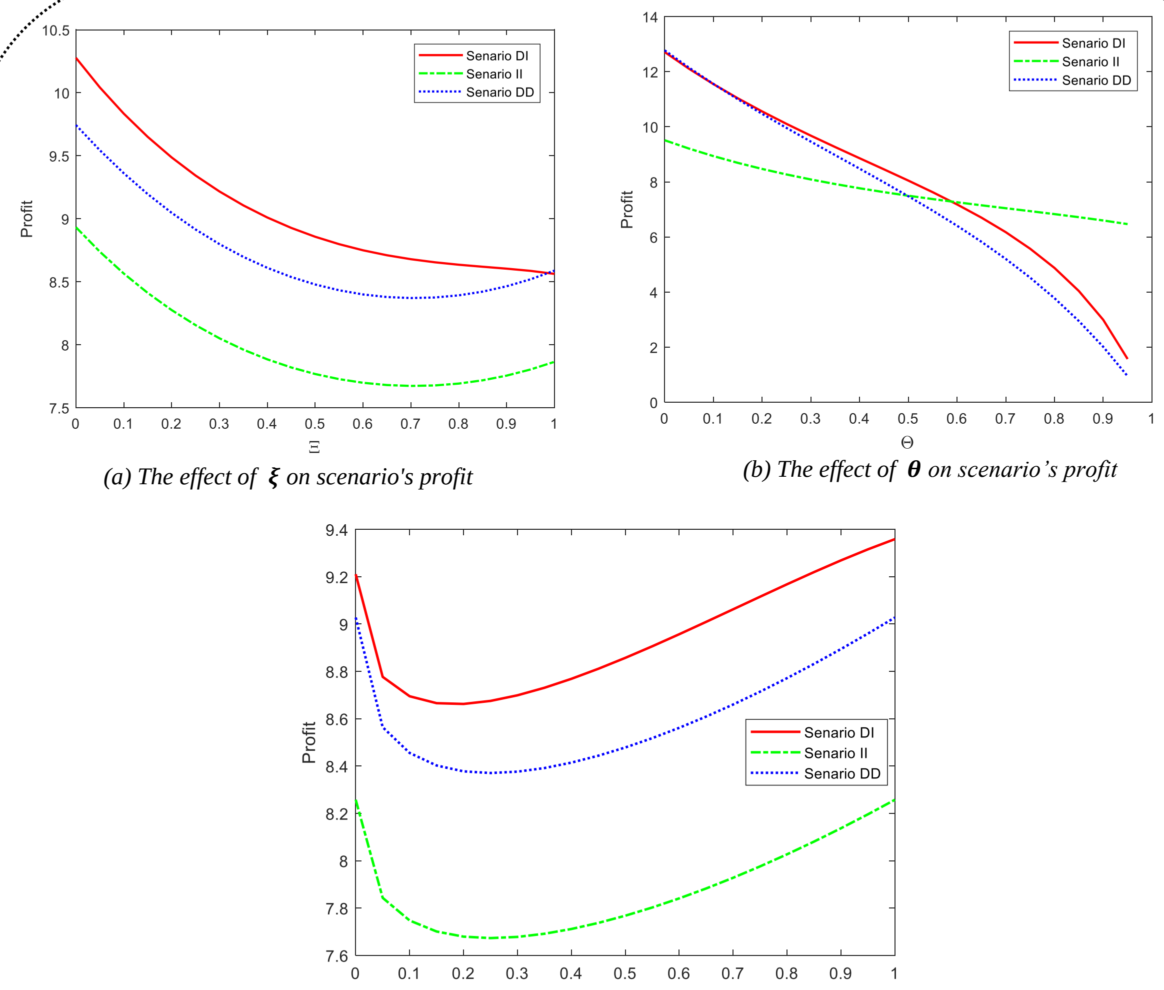
Fig. 4. The effect of parameters ξ, θ, **and y, on players' profit in scenario DI**

However, Fig. 5(b) shows that increasing the substitutability of a product or θ, the total profit level of scenario II will increase more than the other scenarios. It can be concluded that if the amount of θ is close to 1, then the system's total profit in scenario II is higher.

D. Managerial insight

This paper examines the price and quality competition in a two-echelon supply chain consisting of two manufacturers and one retailer. Moreover, we analyze three scenarios when the competitive manufacturers can sell their product directly to the end customer or selling through retailers and determine the optimal strategy. This study suggests the following managerial insights.

- The optimal strategy in scenario DD and scenario II shows that manufacturers must have the same behavior. It means their product has the same quality and same selling price. However, in scenario DI, we have a different strategy for each manufacturer.
- Analyzing three scenarios demonstrates that all players' total profits in scenario DI are more than in the other scenario. If the product's substantiality is high (close to one) or less (close to zero), scenario II respectively has the lowest and highest total profit between all scenarios.



(a) The effect of ξ on scenario's profit

(b) The effect of $\boldsymbol{\theta}$ on scenario's profit

(c) The effect of $\boldsymbol{y}$ on scenario's profit

Fig. 5. The effect of parameters ξ, θ, and y, on scenarios' profit

V. CONCLUSIONS AND FUTURE RESEARCH

We considered a two-echelon supply chain problem that including two competitive manufacturers and one typical retailer. Each manufacturer produces a substitutable product. The demand, cost, competitive pricing behavior, and quality are the other features used in our model. Each competitive manufacturer can sell its product directly or indirectly to the customer. For this reason, we developed three scenarios for delivering the manufacturer's product to the end customer, 1) scenario (II). In this scenario, the competitive manufacturers sell their substantiality products to familiar retailers, and then the retailer sells the products to the end customer. It is a symmetric scenario because both manufacturers have the same behavior. 2) scenario (DD): in this scenario, the manufacturer sells its product directly to customers without using a familiar retailer. It is a symmetric scenario as scenario II, but in the 3) scenario (ID) on of the manufacturer deliver the product to the end customer through a typical retailer and the other of manufacturer sell directly to the customer, this scenario is asymmetric because the manufacturer behavior is different. Finally, for each scenario, some numerical example is given to illustrate the variable behavior such as demand and profit of each player of the proposed scenarios in the supply chain model. The results are briefly summarized below:

a) In Scenario DD, it was found that the increase of θ and ξ resulted in a decrease in the quality and sales price, and consequently, the demand and profit of the manufacturer decreased. However, about y, we saw the opposite behavior.
b) In scenario II, we see the new player, a retailer who delivered two manufacturer products to the end customer. In the sensitivity analysis, we saw the same behavior in the DD scenario. Wholesale price (w) had the same behavior as sales price (p), but we saw a different behavior in retailer's profit, for example, increasing the value of θ, contrary to the decline in manufacturers' profit, the retailer' profit rose.
c) In the two previous scenarios, we saw two manufacturers' symmetric behavior, but in scenario DI, this changed. In the analysis, we examined the behavior of products' demand for each parameter. y and ξ behaved contrary to each other in affecting sales price and quality variables. Nevertheless, θ changes had no significant impact on the quality. The result showed that the lowest profit was for the retailer, while in Scenario II, the opposite was true.
d) Finally, compare the total profit made in any scenario we examined. The results showed that the total profit for players in the DI scenario is greater than the DD scenario, as well as changes θ can increase the total profit of scenario II from two other scenarios.

As future research, this paper can be extended in many directions. We assumed that there is no advertising or return policy for the competitive manufacturer in their products. So encouraging the customers to purchase the product by advertising or return policy can consider as future research. As another future research, this model can be extended under stochastic demand on the structure of behavior. Finally, it would be of interest to examine the case of vertical and horizontal competition between the manufacturers and retailers.

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